Fig. 1

UTRAN

WGW (PVG 15K)

PP 5430/ PP 6400

PP 2430/ PP ARN

IP

CS2000/C S3000

UAS

ATM or IP Network

CMTS1000

HFC

PACKET PORT

MG4K/ CVX1800/P VG

PVG

ATM

PP4460

PSTN

UE IMAS/ UE9000

IAD

UEMG

Fig. 2

Impact of codec (Ie)

R Decrement/Transcode

25 20 15 10 5 0

| POTS | Europe Mobile | Sub-marine | Voice over Cable | Voice over DSL | USA Cellular |

G.711 (0 ms)
GSM EFR (100 ms)
G.726-32k (30 ms)
G.729 (35 ms)
G.729A+VAD (35 ms)
G.723.1-6.3k (98 ms)
IS-96a-QCELP (100 ms)

Impact of Delay (Ie)

R

100
90
80
70
60
50

0 100 200 300 400 500

One-way Delay (ms)

G.711
G.726
G.723.1

User Satisfaction

Very satisfactory

Satisfactory

Some users dissatisfied

Many users dissatisfied

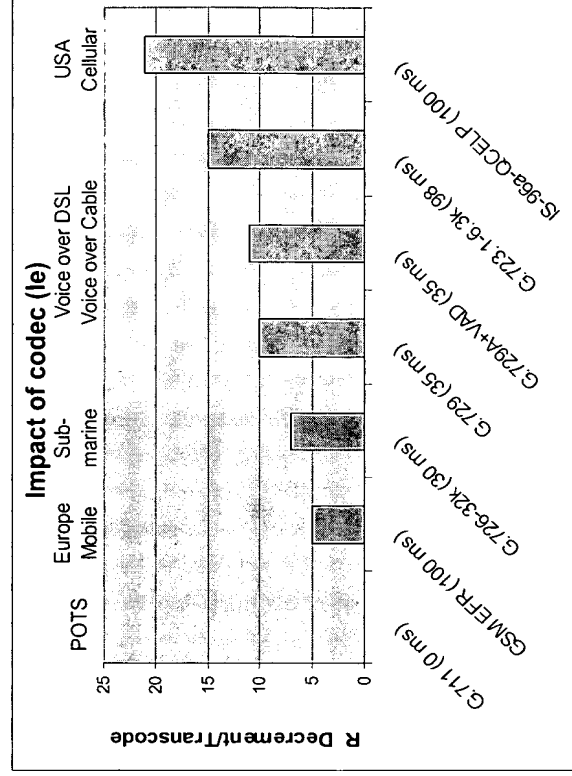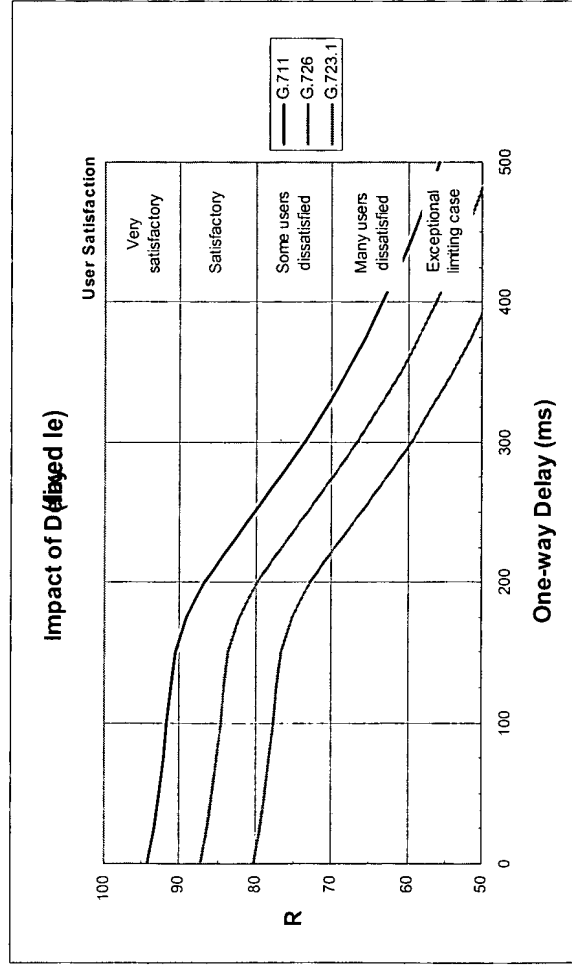Exceptional limiting case

Fig. 3

Figure B.1/G.107 - GOB (Good or Better) and POW (Poor or Worse) as functions of rating factor R
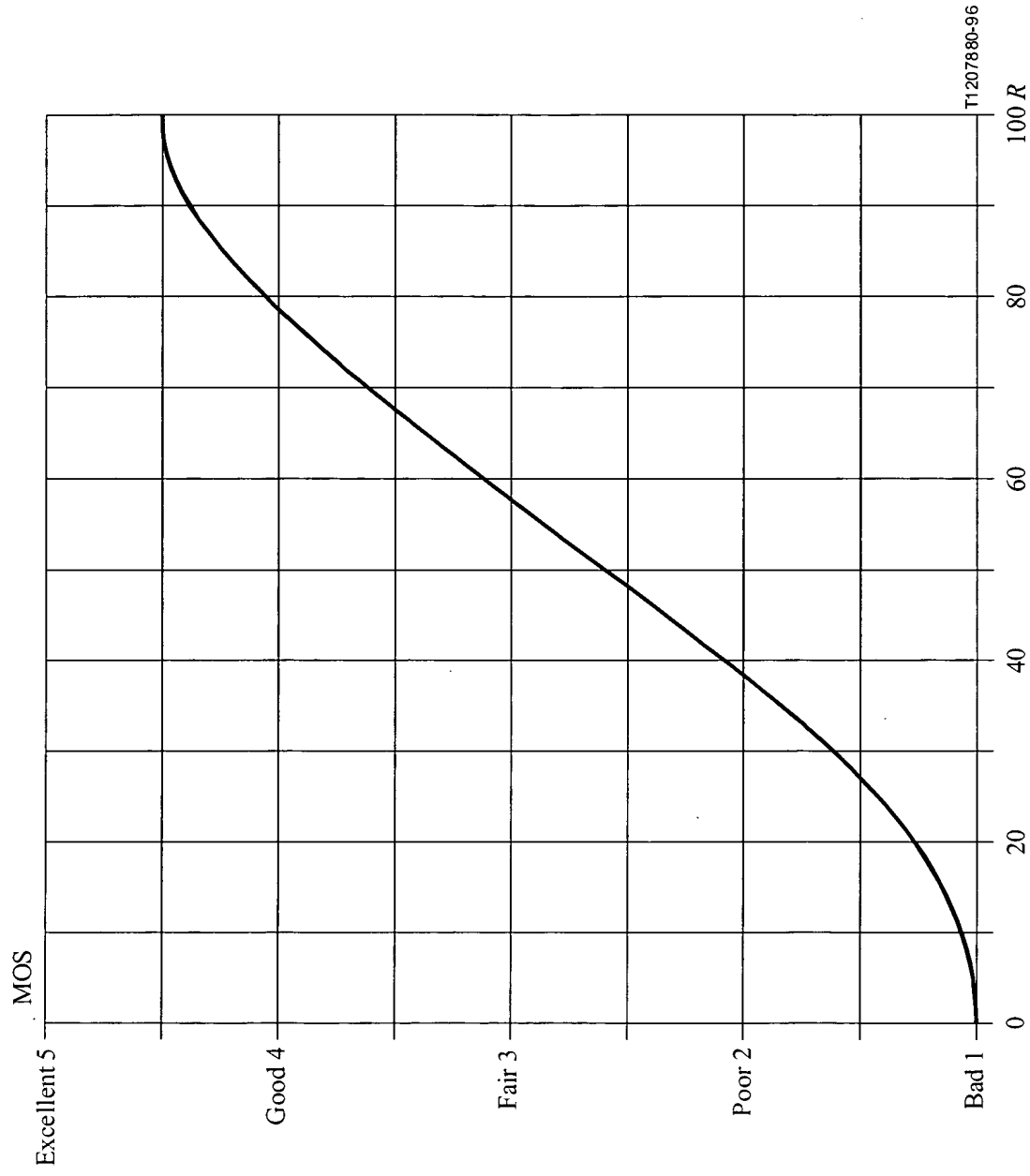
Fig. 4

MOS

Excellent 5

Good 4

Fair 3

Poor 2

Bad 1

0   20   40   60   80   100 R

T1207880-96

Figure B.2/G.107 – MOS as function of rating factor R

Fig. 5

R	USER SATISFACTION	MOS
100		4.4
94 →	**Very Satisfied**	4.3
90		
80		4.0
70		3.6
60		3.1
50	**Nearly All Users Dissatisfied**	2.6
0	**Not Recommended**	1.0

Best
Possible
Narrowband
Result

Fig. 6

PSTN

PSTN

GSM

ATM or IP
Network

ATM or IP
Network

ATM or IP
Network

PSTN

GSM

GSM

Fig. 7

USER SATISFACTION

Very Satisfied

Nearly All Users Dissatisfied

Not Recommended

			R
			100
			94
			90
			80
			70
			60
			50
			0

POTS to POTS (P-P)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
87.8	85.8	76.8	66.6

POTS to Mobile (P-M)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
81.7	70.6	59.8	49.4

Mobile to Mobile (M-M)

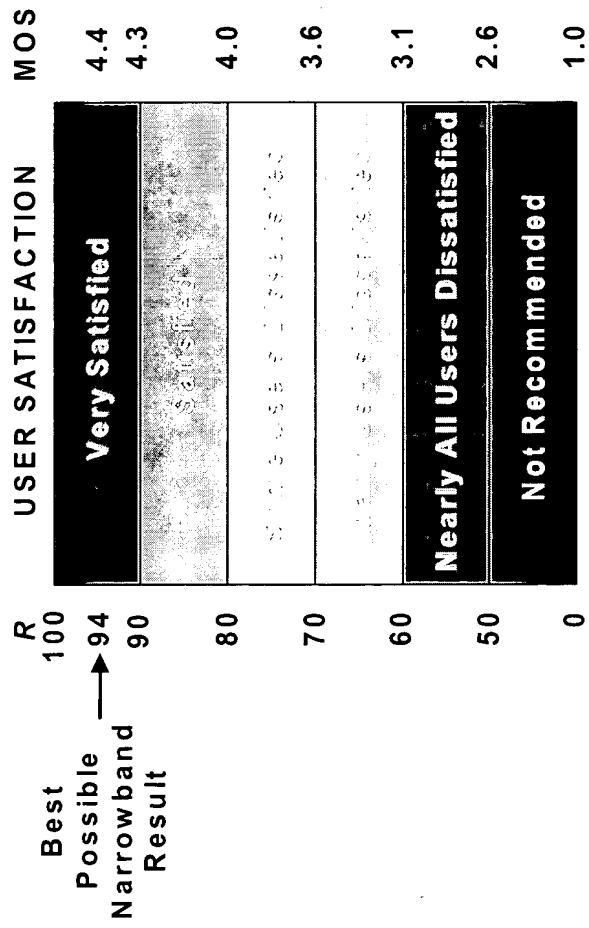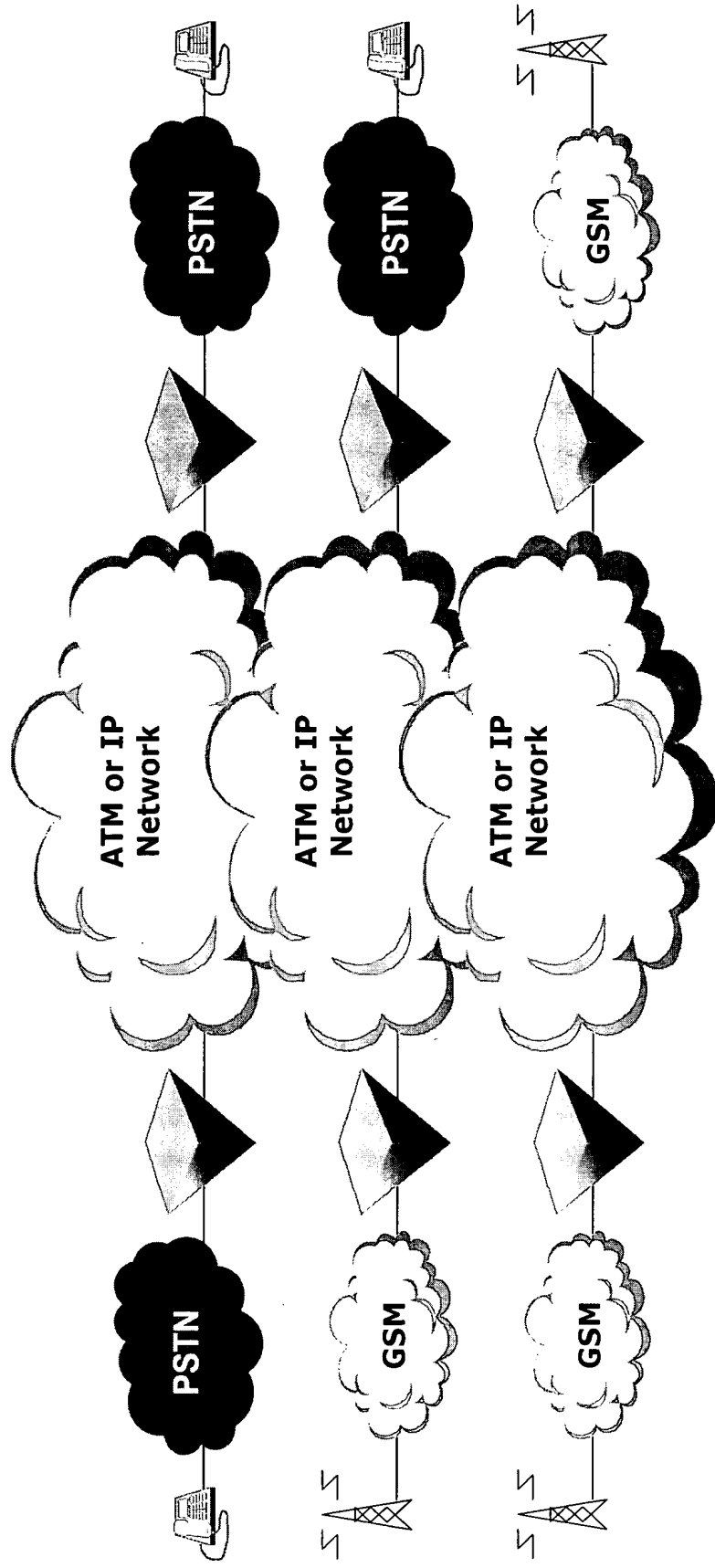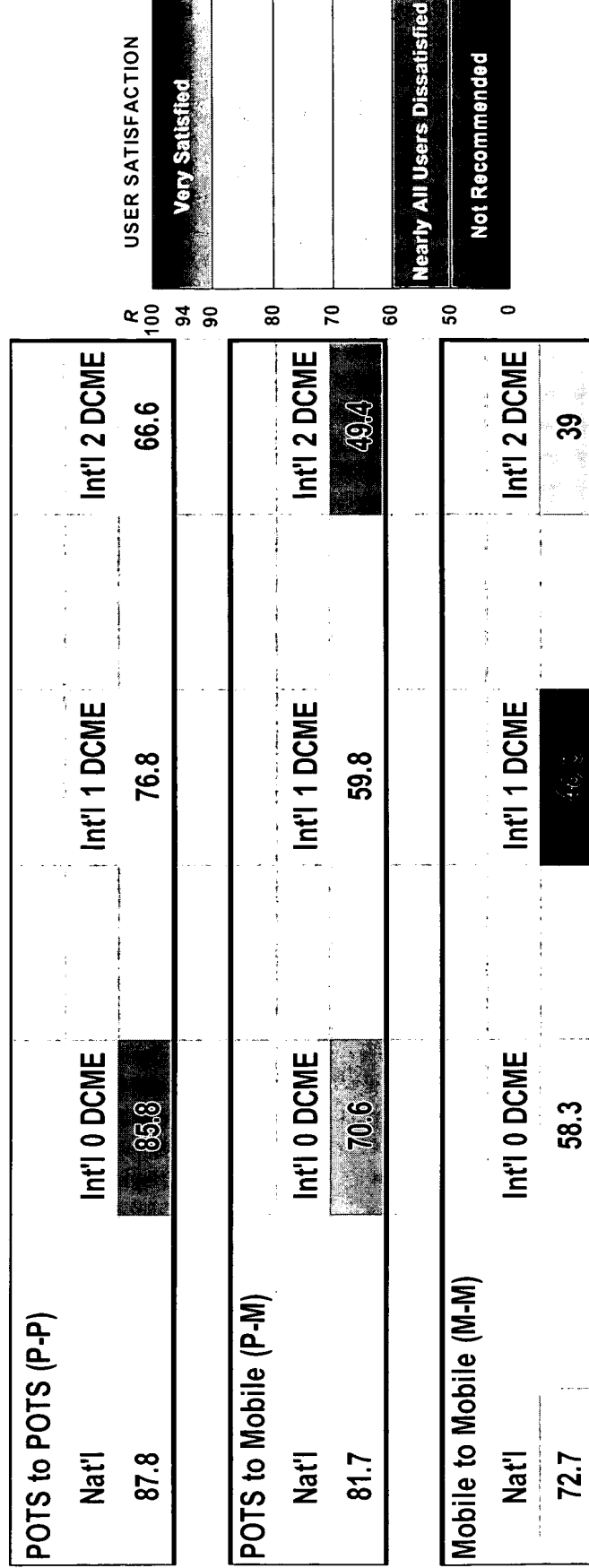| Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
72.7	58.3		39

Limit of acceptability - a hard threshold

Mobile is GSM EFR.
POTS is modelled for an analogue set.
Nat'l = 8000km, Int'l = 27500km.

Fig. 8

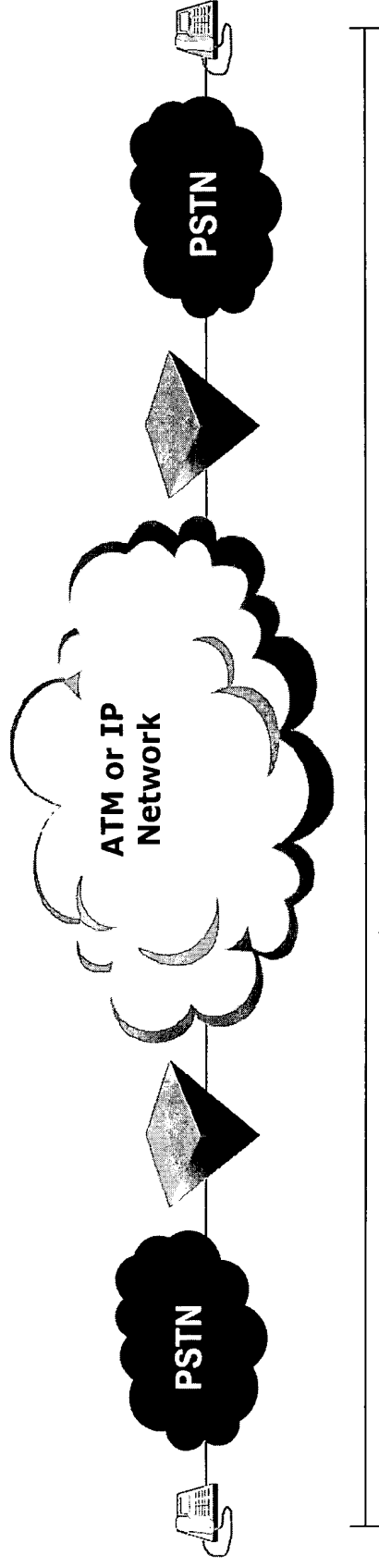What reference calls will be the most demanding quality measure?

Fig. 9

This?

Or this?

PSTN

ATM or IP Network

PSTN

ATM or IP Network

PSTN

PSTN

ATM or IP Network

PSTN

Fig. 10

	Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
POTS to POTS (P-P)	87.8	85.8	76.8	66.6
POTS to Mobile (P-M)	81.7	70.6	59.8	49.4
Mobile to Mobile (M-M)	72.7	58.3		39

USER SATISFACTION

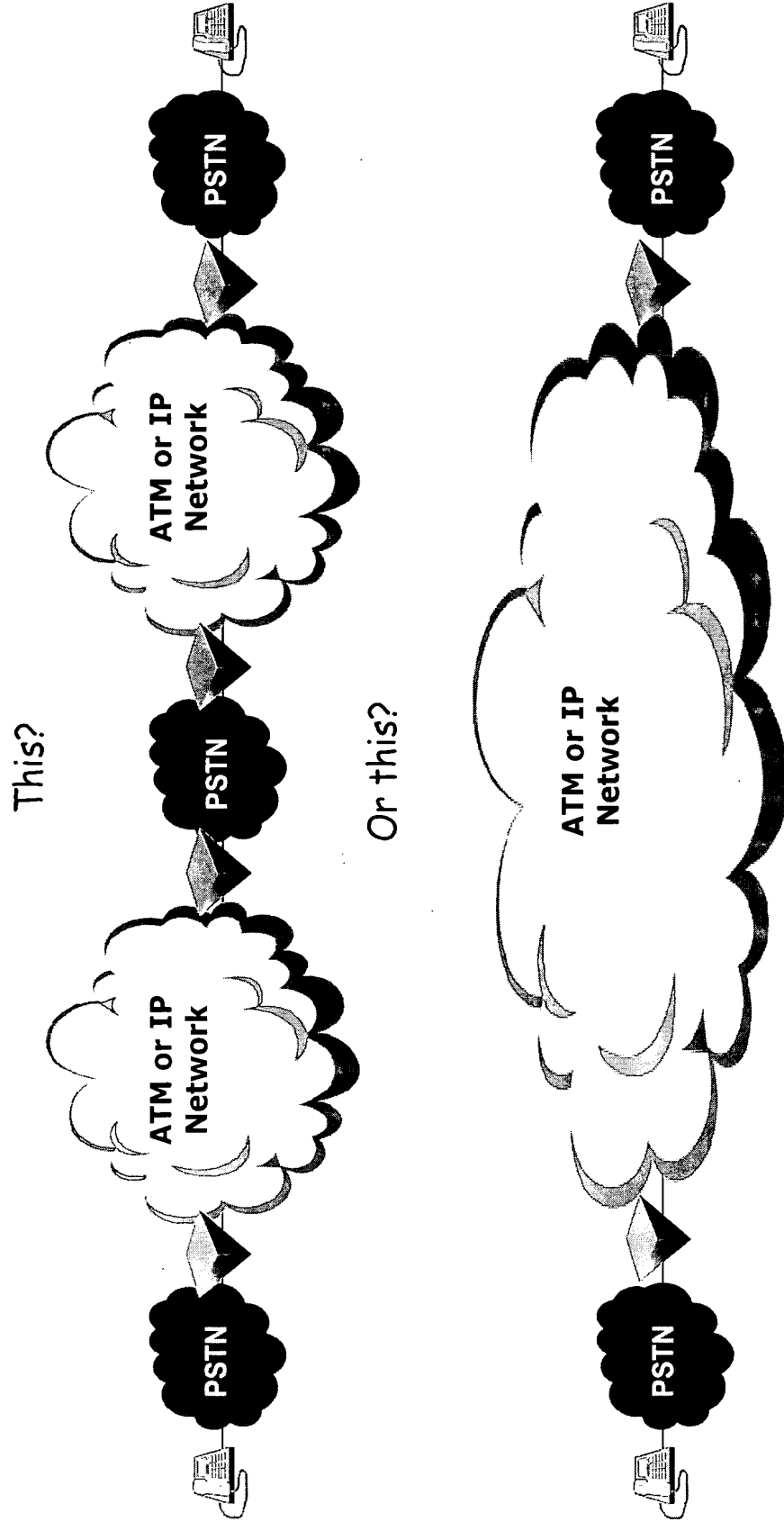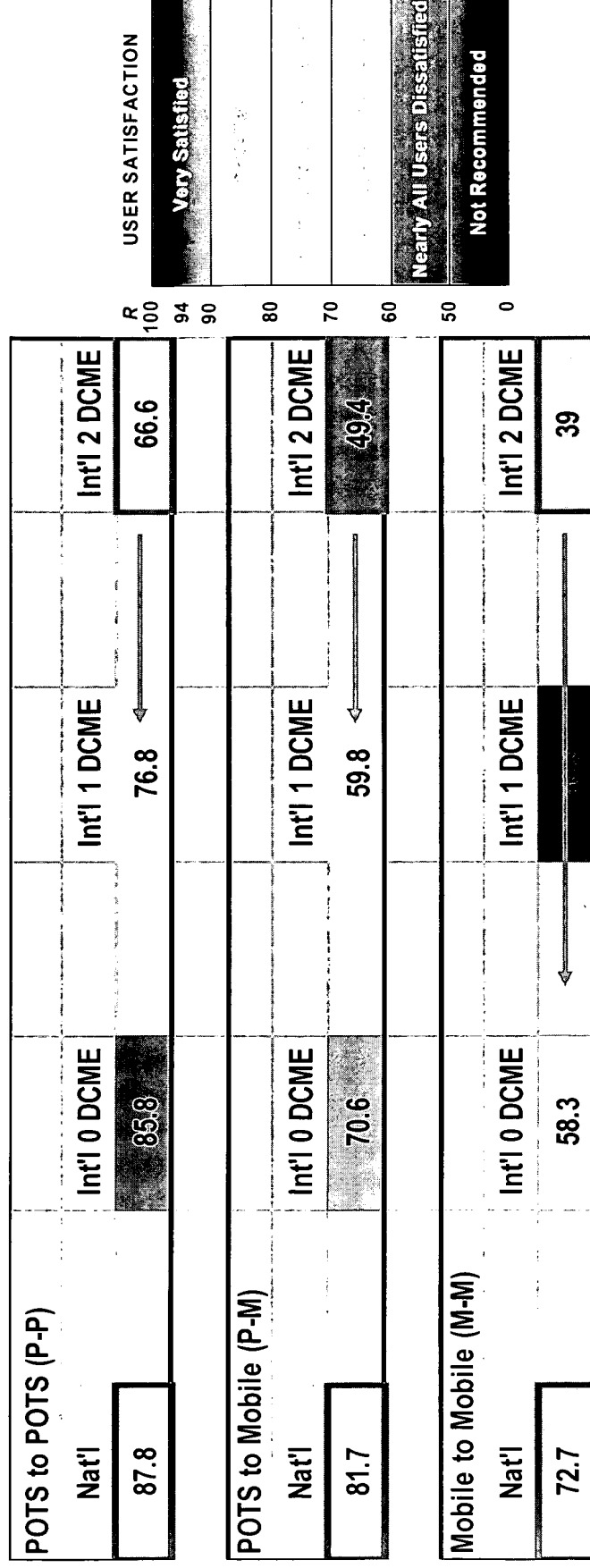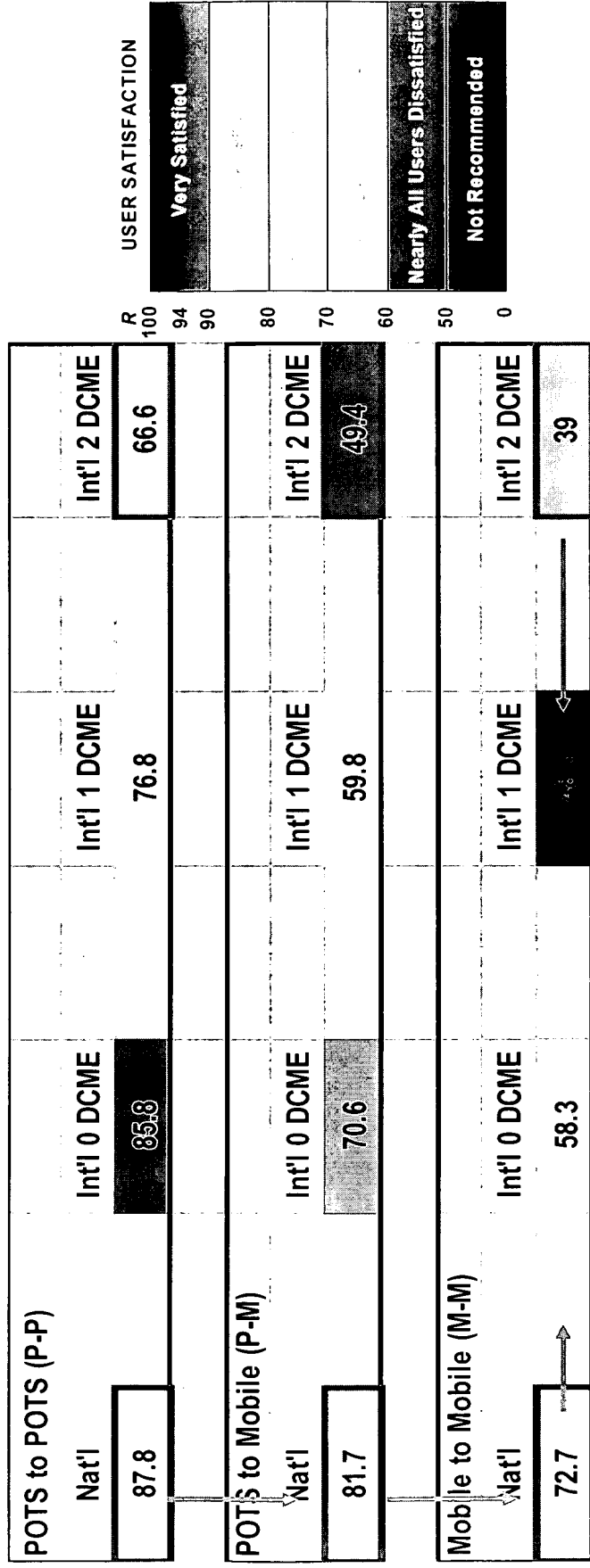| R	
100	Very Satisfied
94	
90	
80	
70	
60	Nearly All Users Dissatisfied
50	
0	Not Recommended

Limit of acceptability - a hard threshold

Mobile is GSM EFR, POTS is modelled for an analogue set. Nat'l = 8000km, Int'l = 27500km.

(*5R = 0.2 MOS over most of the linear range considered in the statistical noise by many practitioners.)

Fig. 11

USER SATISFACTION

Very Satisfied	
Nearly All Users Dissatisfied	
Not Recommended	

R
100
94
90
80
70
60
50
0

POTS to POTS (P-P)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
87.8	85.8	76.8	66.6

POTS to Mobile (P-M)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
81.7	70.6	59.8	49.4

Mobile to Mobile (M-M)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
72.7	58.3		39

Limit of acceptability - a hard threshold

Mobile is GSM EFR, POTS is modelled for an
analogue set. Nat'l = 8000km, Int'l = 27500km.

Fig. 12

POTS to POTS (P-P)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
87.8	85.8	76.8	66.6

POTS to Mobile (P-M)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
81.7	70.6	59.8	49.4

Mobile to Mobile (M-M)

Nat'l	Int'l 0 DCME	Int'l 1 DCME	Int'l 2 DCME
72.7	56.3	48.3	39

Limit of acceptability - a hard threshold

Mobile is GSM EFR, POTS is modelled for an
analogue set. Nat'l = 8000km, Int'l = 27500km.

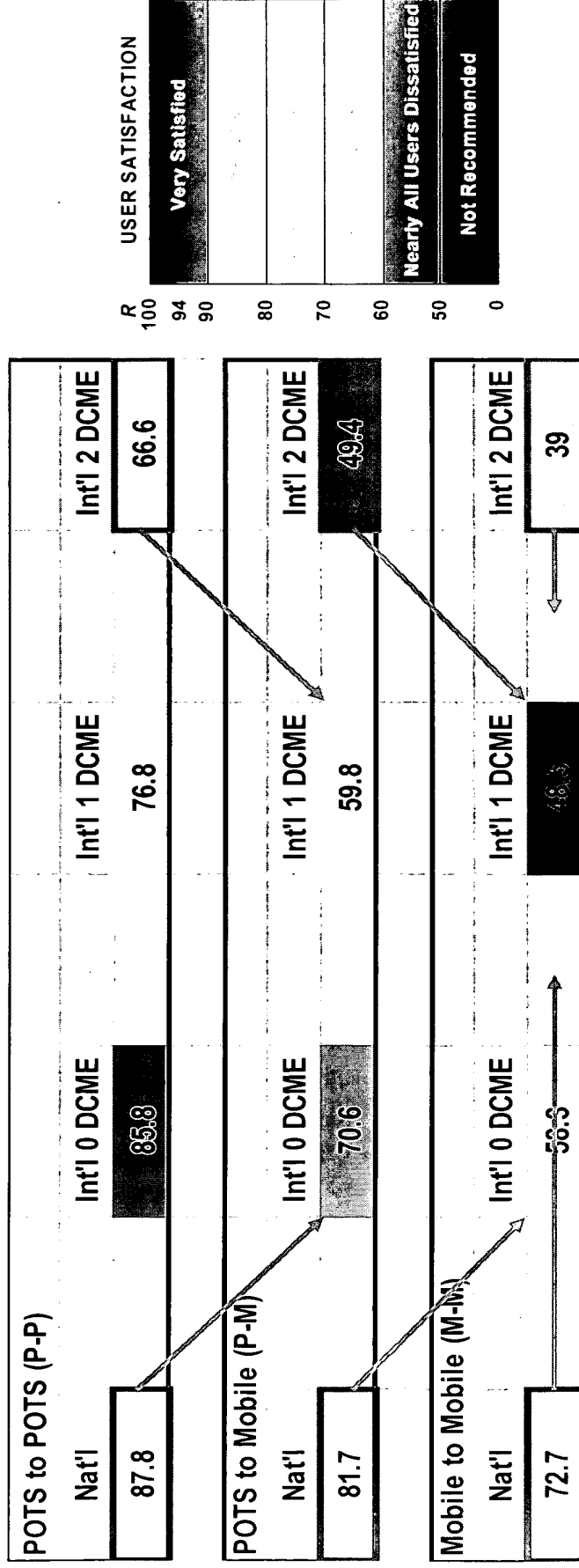## USER SATISFACTION

R	
100	Very Satisfied
94	
90	
80	
70	
60	Nearly All Users Dissatisfied
50	Not Recommended
0	

Fig. 13

EO - End Office
TO - Tandem Office
T2AMG - TDM trunk to AAL-1/2 MG
T2IMG - TDM trunk to VoIP MG
LIT - Lawful Intercept Tap

ATM Sw

IP Rout

T2AMG

ECAN
ECAN

T2IMG

ATM Sw

T2AMG

ECAN

TO

LIT

LIT

LIT

national distance

national distance (TO equiv.)

Fig. 14

L2AIMG
ECAN

ATM
Sw

IP
Rout

LIT

LIT

national distance (TO equiv.)

L2AIMG - TDM line to AAL-1/2 & VoIP MG
LIT - Lawful Intercept Tap

Fig. 15

V2AIMG - VoDSL to AAL-1/2 & VoIP MG
LIT - Lawful Intercept Tap
CLE - Customer Located Equipment

CLE

ECAN
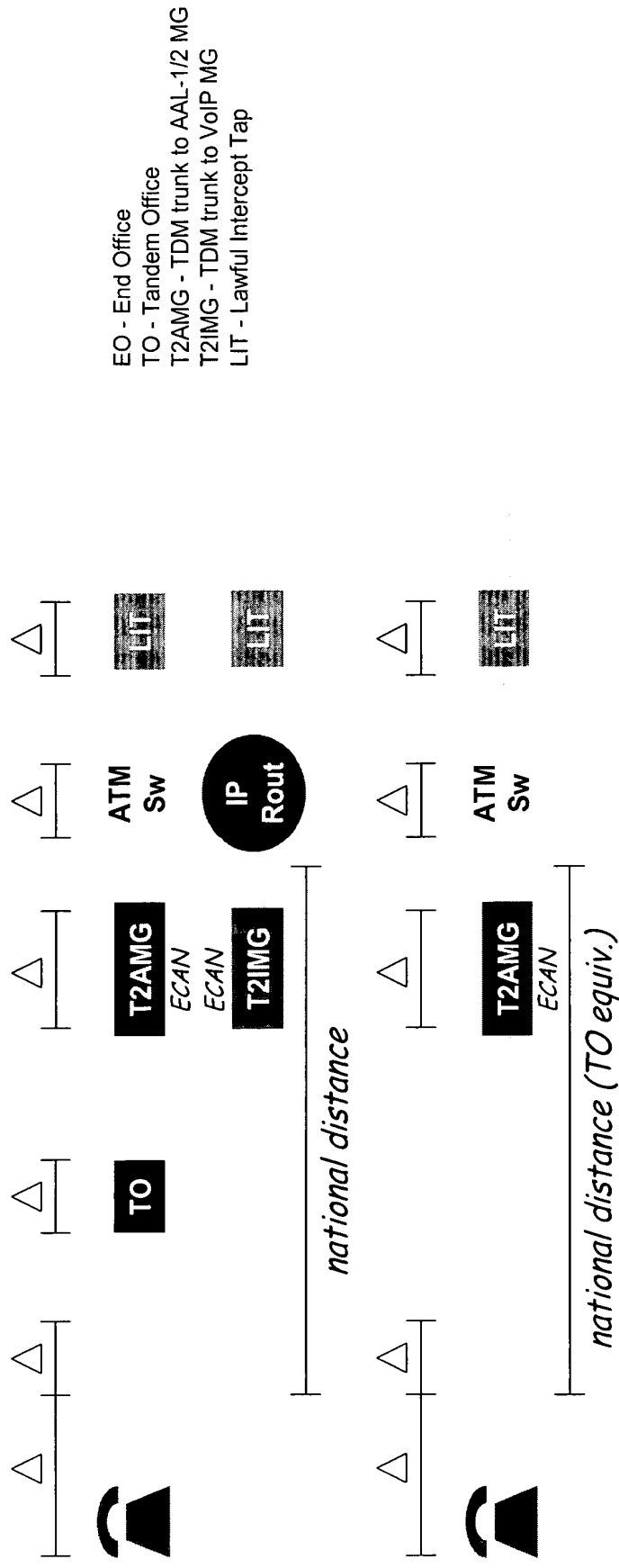
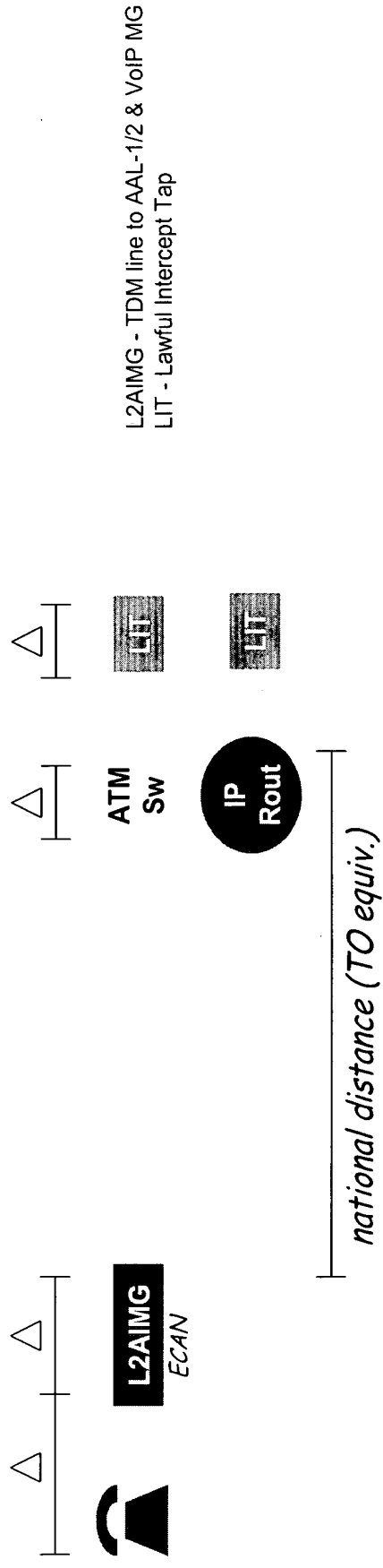V2AIMG

national distance (TO equiv.)

ATM
Sw

IP
Rout

LIT

LIT

ECAN

Fig. 16

MRIMG - Mux Relay & Interworking MG
LIT - Lawful Intercept Tap
CLE - Customer Located Equipment
CPE - Customer Premises Equipment
PVG - Passport Voice Gateway
EO - End Office
TO - Tandem Office
MG4K - TDM to AAL-1 MG
CVX1800 - TDM to VoIP MG
15KMSS - Passport 15K ATM Sw
V15K - Versalar 15K IP router

CLE/CPE
ECAN???

PVG
ECAN???

TO

MG4K
ECAN???

15KM
SS

MRIMG

CVX1800

V
15K

ATM
Sw
Rout

national distance   (TO equiv.)

LIT

LIT

LIT

Not recommended, but
may be unfortunate reality

Fig. 17

ECAN

iPBX

IP Rout

Fire/GW

IP Rout

LIT

Not recommended, but may be near-term reality

TO

MG4K
ECAN???

CVX1800

15KM SS

V 15K

LIT

LIT

campus range

national distance (TO equiv.)
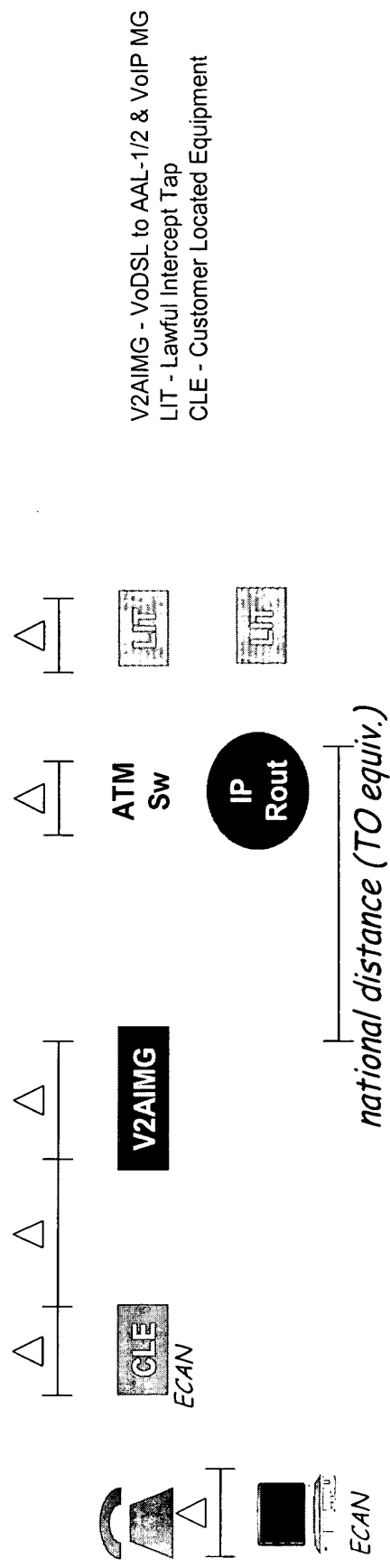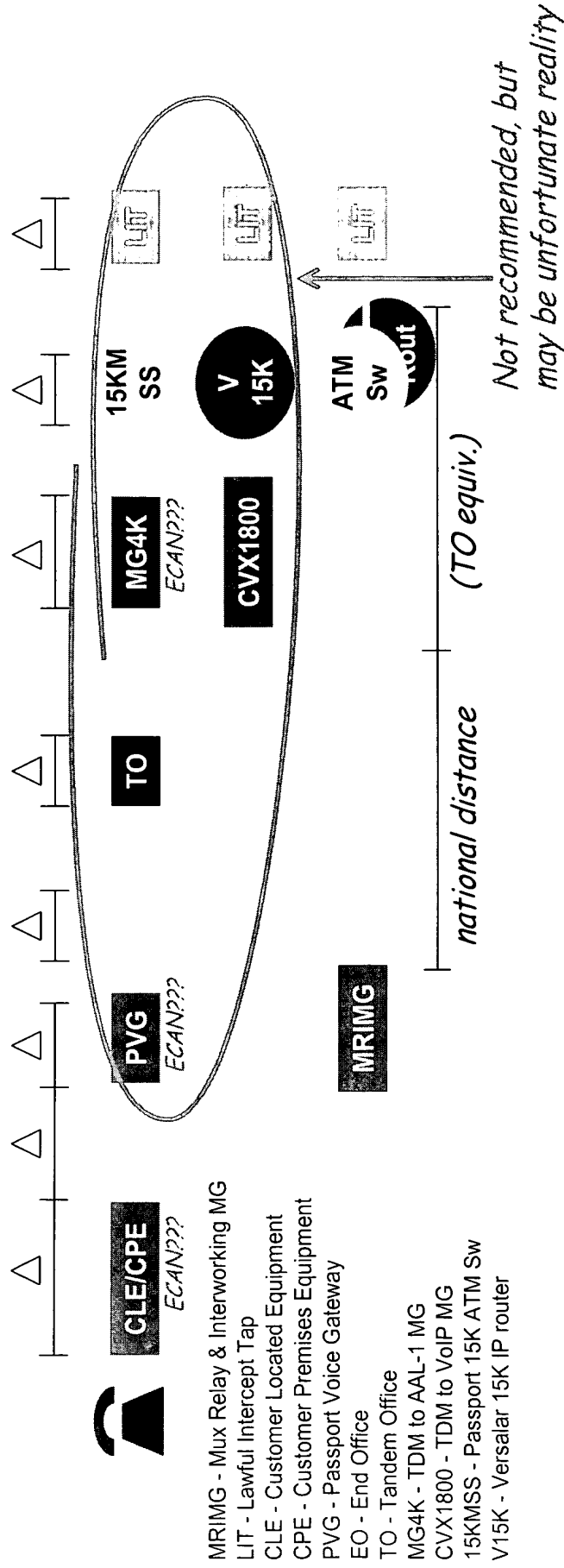
MRIMG - Mux Relay & Interworking MG
LIT - Lawful Intercept Tap
CLE - Customer Located Equipment
CPE - Customer Premises Equipment
PVG - Passport Voice Gateway
EO - End Office
TO - Tandem Office
MG4K - TDM to AAL-1 MG
CVX1800 - TDM to VoIP MG
15KMSS - Passport 15K ATM Sw
V15K - Versalar 15K IP router

Fig. 18

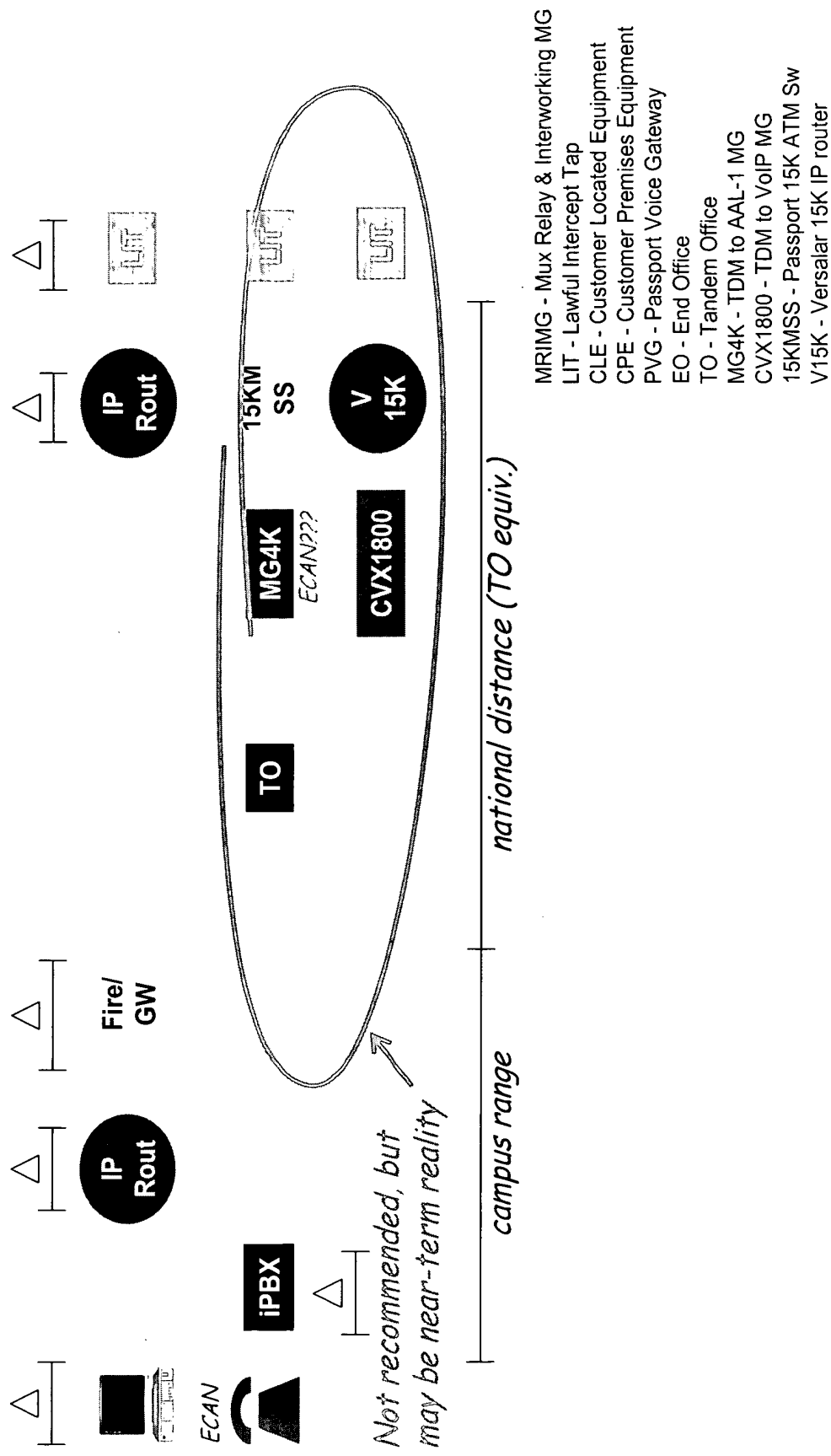LIT - Lawful Intercept Tap
PP - Cable Modem (Packet Port)
CMTS - Cable Head End

PSTN TO and MG already considered eliminated in ATT packet cable bid.

ATM Sw

IP Rout

national distance (TO equiv.)

CMTS

HFC

8-32km

PP

ECAN

ECAN

Fig. 19

BTS △ △ △ △

BSC △ △ △

MSC
ECAN △

MG4K △

15KM SS △

LIT △

CVX1800

15KV ers.

LIT

national distance (TO equiv.)

GSM, CDMA

Node B △ △ △ △

RNC △ △ △

WGW + LIT + IMG △

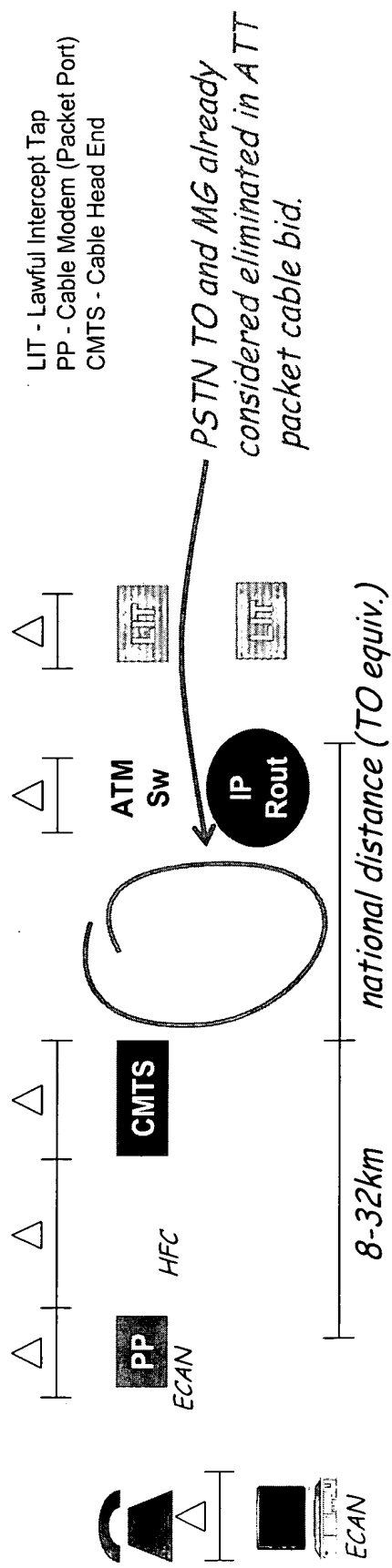**ATM Sw**

Rout

national distance (TO equiv.)

3G Wireless

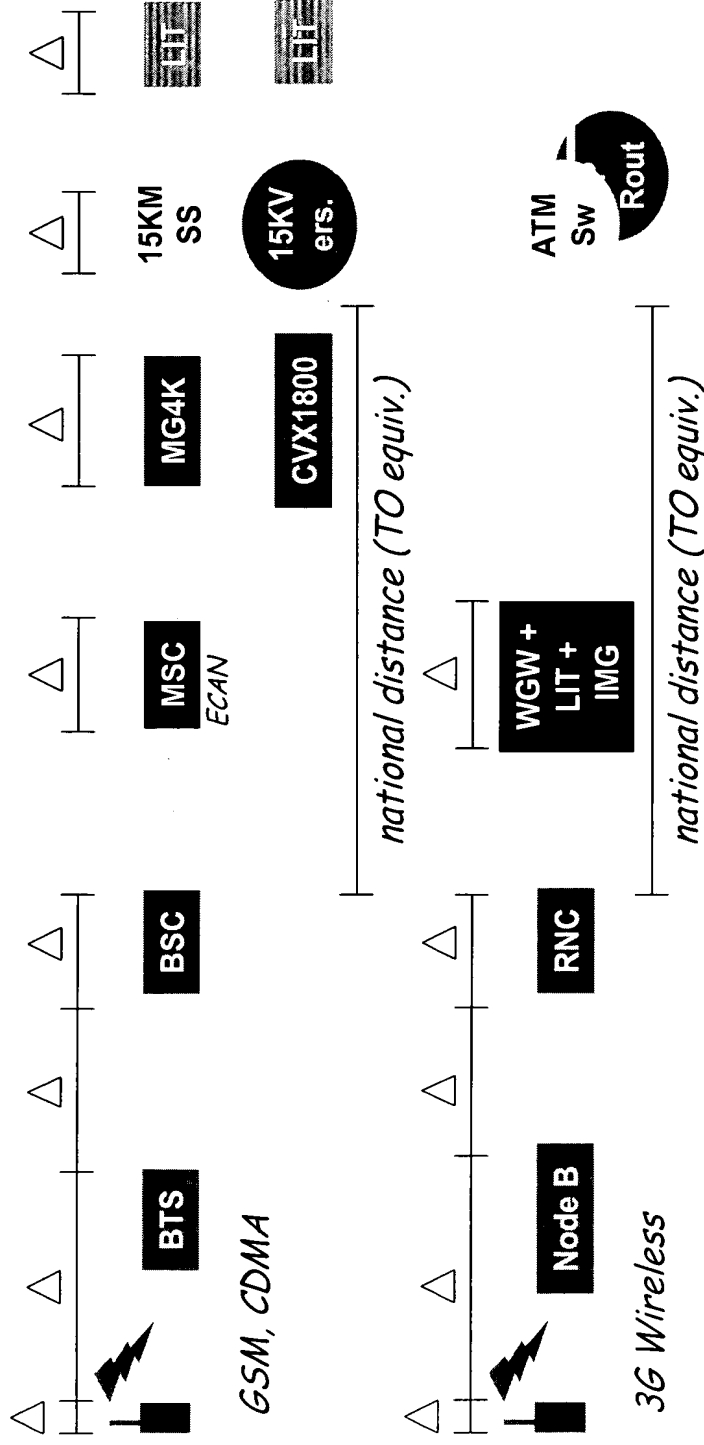
LIT - Lawful Intercept Tap
BTS - Base Station
BSC - Base Station Controller
MSC - Mobile Switching Centre &
    Transcoding Unit (Mob - TDM)
MG4K - TDM to AAL-1 MG
CVX1800 - TDM to VoIP MG
15KMSS - Passport 15K ATM Sw
V15K - Versalar 15K IP router
Node B - Radio and soft HO function
RNC - Radio Network Controller &
    softer HO, DHO functions
WGW - Wireless Gateway and anchor

Fig. 20

27,500km - 2*(distance from subs to TO equiv.)

lumped national model   lumped international model   lumped national model

lumped national model

Fig. 21

Background noise

Send side

- Transmit level
- Handset transmit noise suppression

Local telephone impairments

Network impairments

- Electrical loss
- Circuit noise
- Equipment noise floor
- Quantizing distortion
- Equipment impairment factor
- Absolute delay
- Echo path delay
- Talker echo path loss
- Listener echo path loss

Local telephone impairments

- Receive level
- Talker sidetone
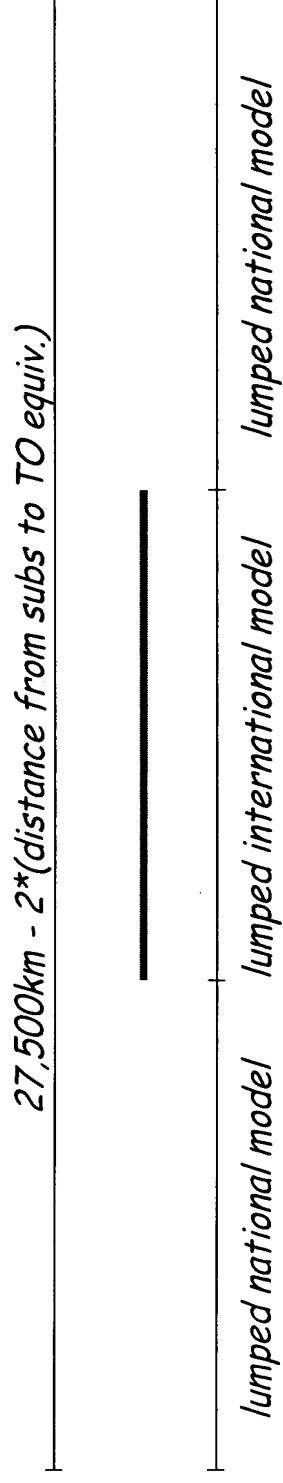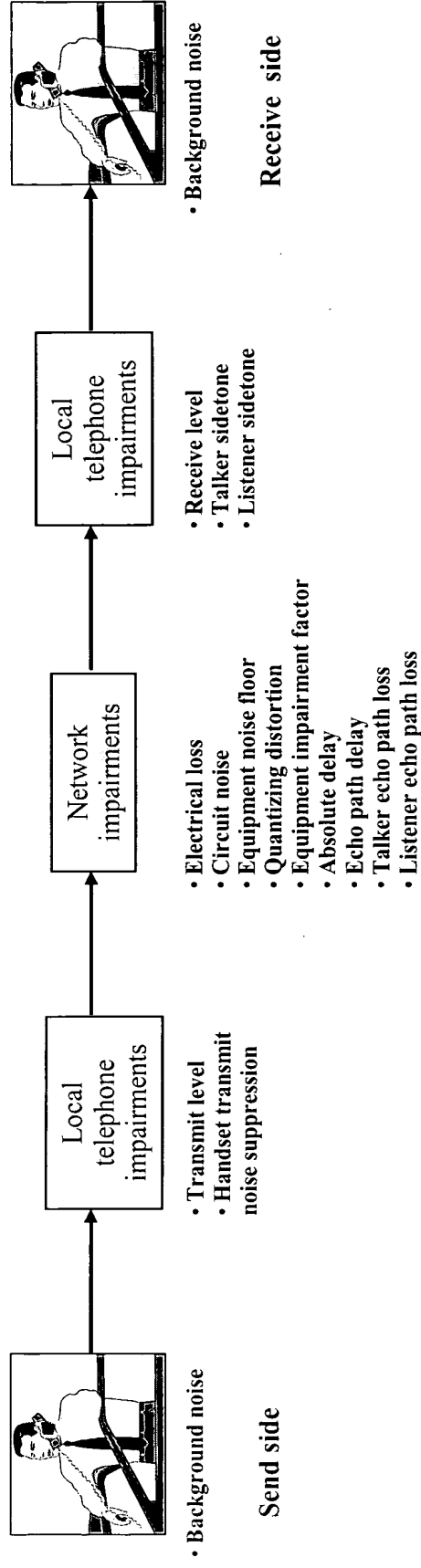- Listener sidetone

- Background noise

Receive side

The E-model calculates a **Transmission Rating Factor** R, given by

$$R = R_o - I_s - I_d - I_e + A$$

Fig. 22

E-Model Parameter Default Values

Parameter	Units	Value
SLR (Send Loudness Rating)	dB	8
RLR (Receive Loudness Rating)	dB	2
STMR (Sidetone Masking Rating)	dB	15
LSTR (Listener Sidetone Rating)	dB	18
OLR (Overall Loudness Rating)	dB	10
TELR (Talker Echo Loudness Rating)	dB	65
WEPL (Weighted Echo Path Loss)	dB	110
T (Mean Intrinsic One-Way Delay)	msec	0
Ta (Absolute Delay)	msec	0
Tr (Round-Trip Delay)	msec	0
QDU (Quantization Distortion Units)	-	1
Ie (Equipment Impairment Factor)	-	0
A (Expectation Factor)	-	0
Ds (Handset Shape Factor – Send Side)	-	3
Dr (Handset Shape Factor – Receive Side)	-	3
Ps (Room Noise at the Send side)	dB(A)	35
Pr (Room Noise at the Receive side)	dB(A)	35
Nc (Circuit Noise referred to 0 dBr-point)	dBm0p	-70
Nfor (Noise Floor at the Receive Side)	dBmp	-64

Fig. 23

R	USER SATISFACTION	MOS	%GOB	%POW
100				
94		4.4	98.4	0.1
90		4.3	97.0	0.2
80		4.0	89.5	1.4
70		3.6	73.6	5.9
60	Not Recommended (Low)	3.1	50.1	17.4
50		2.6	26.6	37.7
0		1.0	0	99.8

Best possible narrowband result (G.107 Default) → 94

Fig. 24

USER SATISFACTION

Not Reccommended (low)

	G.711 + PLC	G.729A + VAD	G.723.1 + VAD
Packet Loss (%)	0 0 0	0 2	0 2
Packetization+Jitter Buffer Delay (ms)	0 30	35	98 2
Network + Propagation Delay (ms)	0 100	100	100 100

R
94
90
80
70
60
50

Fig. 25

	Ie for E-Model Calculations								
	G.711 [Ref.10] [Notes 2, 3]	G.711 [Notes 1, 2, 3]	G.711 [Notes 1, 2, 3]	G.711 [Notes 1, 2, 3, 4]	G.729A [Notes 1, 3]	G.729A [Ref.10] [Note 3]	G.729A [Notes 1, 3]	G.729A [Notes 1, 3]	G.726 32kb/s note [5]
Frame Size (ms)	.125	.125	.125	.125	10	10	10	10	.125
Packet Payload (ms)	10	20	30	40	10	20	30	40	20
Packet Loss (%)									
0	0	0	0	0	11	11	11	11	7
1	5	8	10	13	13	15	17	19	N/A
2	7	13	16	19	16	19	21	24	N/A
3	10	19	22	24	19	23	25	28	N/A
4	12.5*	22	26	28	22	26	29	32	N/A
5	15	25	30	32	25	29*	32	35	N/A

Notes:

1) In the absence of any supporting documentation, these are arbitrary values
2) All G.711 vocoders are assumed to have PLC (Packet Loss Concealment) algorithms
3) Impairment factors apply for random packet loss conditions
4) This is the current capability of the i2004 (in the absence of any download instructions to achieve smaller frame size)
5) There is no PLC algorithm for G.726, therefore its deployment might be limited in lossy network
6) Interpolated values

Fig. 26

User Satisfaction

- G.711
- G.729A
- G.723.1

Very satisfactory

Satisfactory

Some users dissatisfied

Many users dissatisfied

Exceptional limiting case

R

One-way Delay (ms)

Fig. 27

User Satisfaction

Very satisfactory	
Satisfactory	
Some users dissatisfied	
Many users dissatisfied	
Exceptional limiting case	

R

100

90

80

70

60

50

0   100   200   300   400   500

One-way Delay (ms)

——— G.726, no transcodes

——— G.729A, no transcodes

——— G.729A - G.726 - G.729A

Fig. 28

G.711 with PLC under conditions of random packet loss

- PL = 0%
- PL = 1%
- PL = 2%
- PL = 3%
- PL = 5%
- PL = 7%
- PL = 10%
- PL = 15%

PL = Packet Loss
PLC = Packet Loss Concealment

User Satisfaction

- Very satisfactory
- Satisfactory
- Some users dissatisfied
- Many users dissatisfied
- Exceptional limiting case

One-way Delay (ms)

R

Fig. 29

User Satisfaction

| Very satisfactory |
| Satisfactory |
| Some users dissatisfied |
| Many users dissatisfied |
| Exceptional limiting case |

One-way Delay (ms)

R

G.729A with PLC under conditions of random packet loss

— G.711
— G.729A, 0%
— G.729A, 1%
— G.729A, 2%
— G.729A, 3%
— G.729A, 4%

PL = Packet Loss
PLC = Packet Loss Concealment

Fig. 30

User Satisfaction

| Very satisfactory |
| Satisfactory |
| Some users dissatisfied |

R

100

90

80

200   300   400

One-way Delay (ms)

Insensitive to delay

Sensitive to le

le and delay can be added equally

In this zone, le and delay can be added with less impact on "R". More appropriate to use a compression codec

If you are in this zone, there is very small room for impairment, I.e. no compression codec

Fig. 31

The contour graphs show the available Delay and le margins for a constant R

R is constant along the curve

Clarity, R = 66.6
Carrot, R = 66.6
Cut, R = 59.8
AIM Clarity R = 73.6

Maximum Delay Margin for Packetization and Jitter

Maximum le Margin for Codec and Packet Loss

0   100   200   300   400   500

0   10   20   30   40

Fig. 32

A- Side User Access
(Trunk or Wireless)

TDM Core
Transport Network

B- side User Access
(Trunk or Wireless)

Fig. 33

POTS

Title	Abbreviation (Default)		E-Model Input POTS
Electric Circuit Noise (at 0 dBr)	Nc	(-70 dBmP)	
Room Noise	Po	(35 dBA)	35
Send Loudness Rating	SLR	(8 dB)	11
Receive Loudness Rating	RLR	(2 dB)	3
D-factor	D	(3)	3
Noise Floor	Nfor	(-64 dBm0)	-64
Sidetone Masking Rating	STMR	(15)	15
Equipment Impairment Factor	Ie	(0)	0
Expectation (Advantage) Factor	A	(0)	0
Mean Intrinsic One-Way Delay (upper)	Tu	(0 ms)	0
Mean Intrinsic One-Way Delay (lower)	Tl	(0 ms)	0
Mean Intrinsic One-Way Delay	Tul	(0 ms)	0
Electrical Loss (upper)	Lu	(dB)	0
Electrical Loss (lower)	Ll	(dB)	0
Electrical Loss (upper = lower)	Lul	(dB)	0
Quantizing Distortion Units (upper)	qduu	(1) [Note 1]	0
Quantizing Distortion Units (lower)	qdul	(1) [Note 1]	0
Echo Return Loss	ERL	(dB)	17

Fig. 34
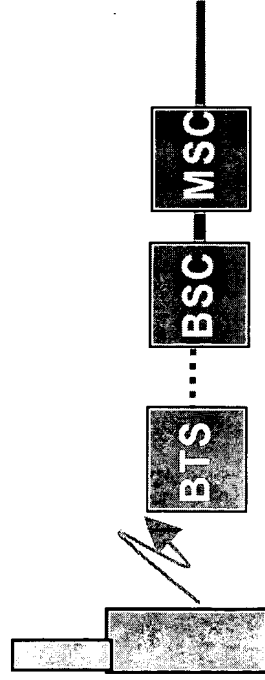
BTS: Base Station
BSC: Base Station Controller
MSC: Mobile Switching Center

PSTN Wireless Access Delay, loss and Impairment Summary	Uplink	Downlink
Mobile Switching Center (MSC) (ms)	1	2
Base Station Controller (BSC) (ms)	2.5	40
Base Station (BTS) (ms)	15.8	40.8
Mobile Set (MS) (ms)	72.1	14.3
PSTN Wireless Access Delay (ms)	91.40	97.10
Impairment Factor (Ie)	5	5

Fig. 35

National TDM Transport Core

TO TO TO TO
ECAN TDM National Transport *ECAN*

International TDM Transport Core

TO TO
TDM National Transport

ISC ISC ISC ISC
ECAN TDM International Transport ECAN

TO TO TO TO
TDM National Transport *ECAN*

International TDM Transport Core with DCME

TO TO
ECAN TDM National Transport

DCME DCME

ISC ISC ISC ISC
TDM International Transport

TO TO TO TO
TDM National Transport *ECAN*

G.711 (TDM/ATM)
G.726 (DCME)

Fig. 36

TDM Core Transport	National (8000km)	International (connection Length 27500 km)			
		0 DCME	1 DCME	2 DCME	3 DCME
National Transmission Time	43	43	43	43	43
T2DCME (G.711/G.726 Conversion+DSI) (ms)	-	0	26	52	78
DCME2T (G.726/G.711 Conversion) (ms)	-	0	2	4	6
International Transmission Time (ms	-	72	72	72	72
National Transmission Time	-	43	43	43	43
Total one-way delay (ms)	43	158	186	214	242
Impairment Factor (Ie)	0	0	7	14	21

Fig. 37

DCME

BTS ···· BSC — MSC

— G.711 (TDM/ATM)
········· Cellular (compressed voice)
▭ G.726 (DCME)

ECAN TO TO TDM National Transport TO TO

DCME / DCME

ECAN TO TO TO TO TDM National Transport

ISC ISC TDM International Transport ISC ISC TO TO TO TO ECAN

PSTN TDM Core Transport with 1 DCME

A- Side Wireless Access

B- side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise)

B- Side Access

PSTN TDM Core Transport

B-Side	National			International DCME			International 1 DCME			International 2 DCME		
	T	Ie	R	T	Ie	R	T	Ie	R	T	Ie	R
Trunk	141.6	5	81.7	253.2		70.6	282.22	12	59.8	310.22	19	49.4
Wireless	231.5	10	72.7	346.5	10	58.3	374.5	17	48.54	402.5	24	38.98

Total E2E Delay (ms)

E-Model "R" factor

Total Impairment

Fig. 38

A-Side Trunk — POTS / EO

TDM Core Transport Network

Described in section 5.1

B-side User Access (Trunk and Mobile)

Described in section 5.2 and 5.3

Trunk Access to	National			International 0 DCME			International 1 DCME			International 2 DCME		
	T	le	R	T	le	R	T	le	R	T	le	R
Trunk	46	0	87.8	161.22	0	85.8	190.22	7	76.8	218.22	14	66.6
Wireless	139.24	5	81.7	253.22	5	70.6	282.22	12	59.8	310.22	19	49.4

Fig. 39

B- side User Access
(Trunk and Mobile)

TDM Core Transport Network

A-Side Wireless

BTS: Base Station
BSC: Base Station Controller
MSC: Mobile Switching Center

Described in section 5.2 and 5.3

Described in section 5.1
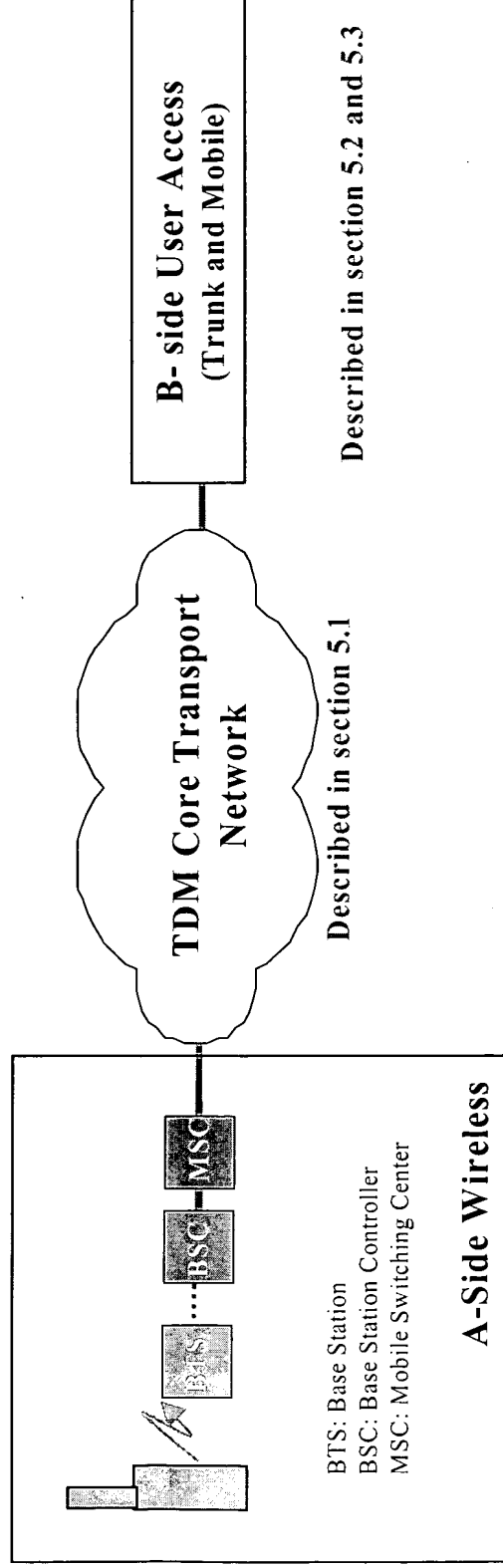
Wireless Access to	National			International 0 DCME			International 1 DCME			International 2 DCME		
	T	le	R	T	le	R	T	le	R	T	le	R
Trunk	141.6	5	81.7	253.2	5	70.6	282.22	12	59.8	310.22	19	49.4
Wireless	231.5	10	72.7	346.5	10	58.3	374.5	17	48.54	402.5	24	38.98

Fig. 40

A- Side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

Core Transport Network
(TDM, ATM or IP)

B- side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

Cable Access - ATM Core

HFC

CABLE CPE

POTS

Trunk Access - ATM Core

POTS — EO — TO — T2A MG

Wireless Access - IP Core

BTS ... BSC — MSC — T2I MG — X core Router

Fig. 41

| A- Side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise) | Core Transport Network (TDM,ATM or IP) | B- side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise) |

ADSL Access - IP Core

core Router

V2I MG

DSL CPE

POTS

Enterprise Multi-Service SW Access

ATM Core

ATM SW

Edge SW

MKTMG

Multi Service SW

T1/ ATM

TDM

PBX

POTS

L2 Switch

Fig. 42

A - Side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise)	Core Transport Network (TDM,ATM or IP)	B- side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise)

Enterprise IPPBX Access
IP Core

IP
PBX

POTS

Firewall

Edge
Router

Edge
Router

L2
Switch
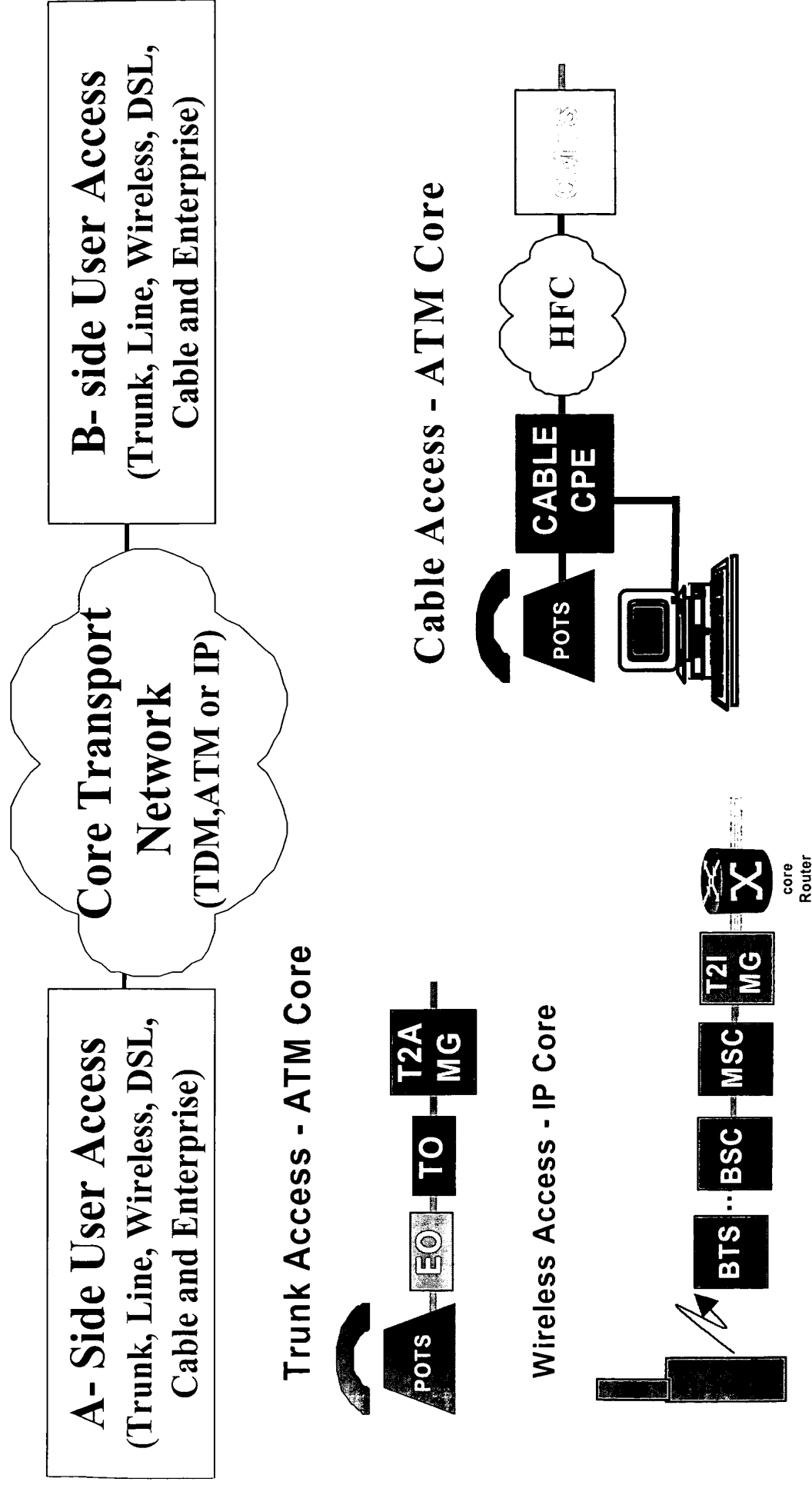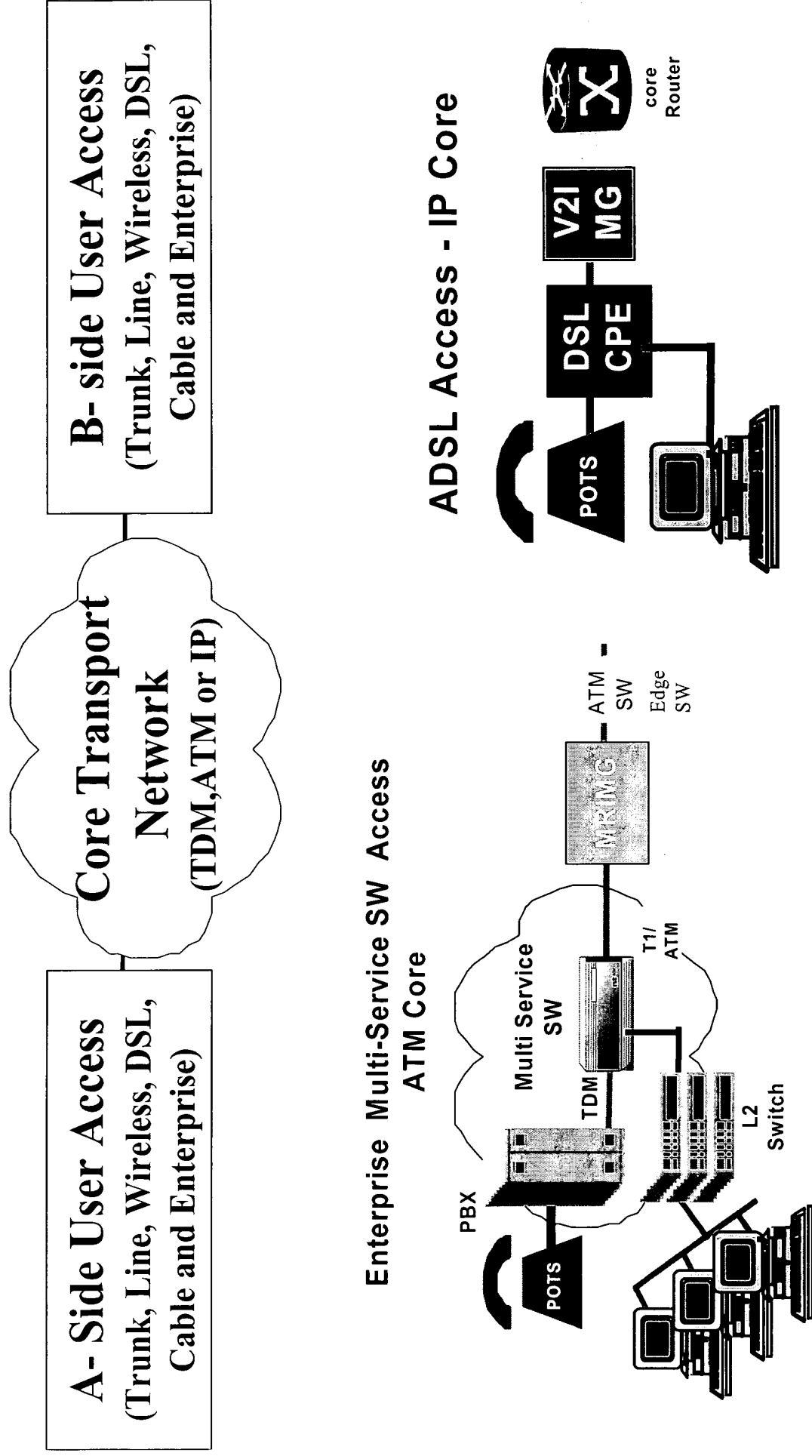
Fig. 43

Which impairments are being considered in the models?
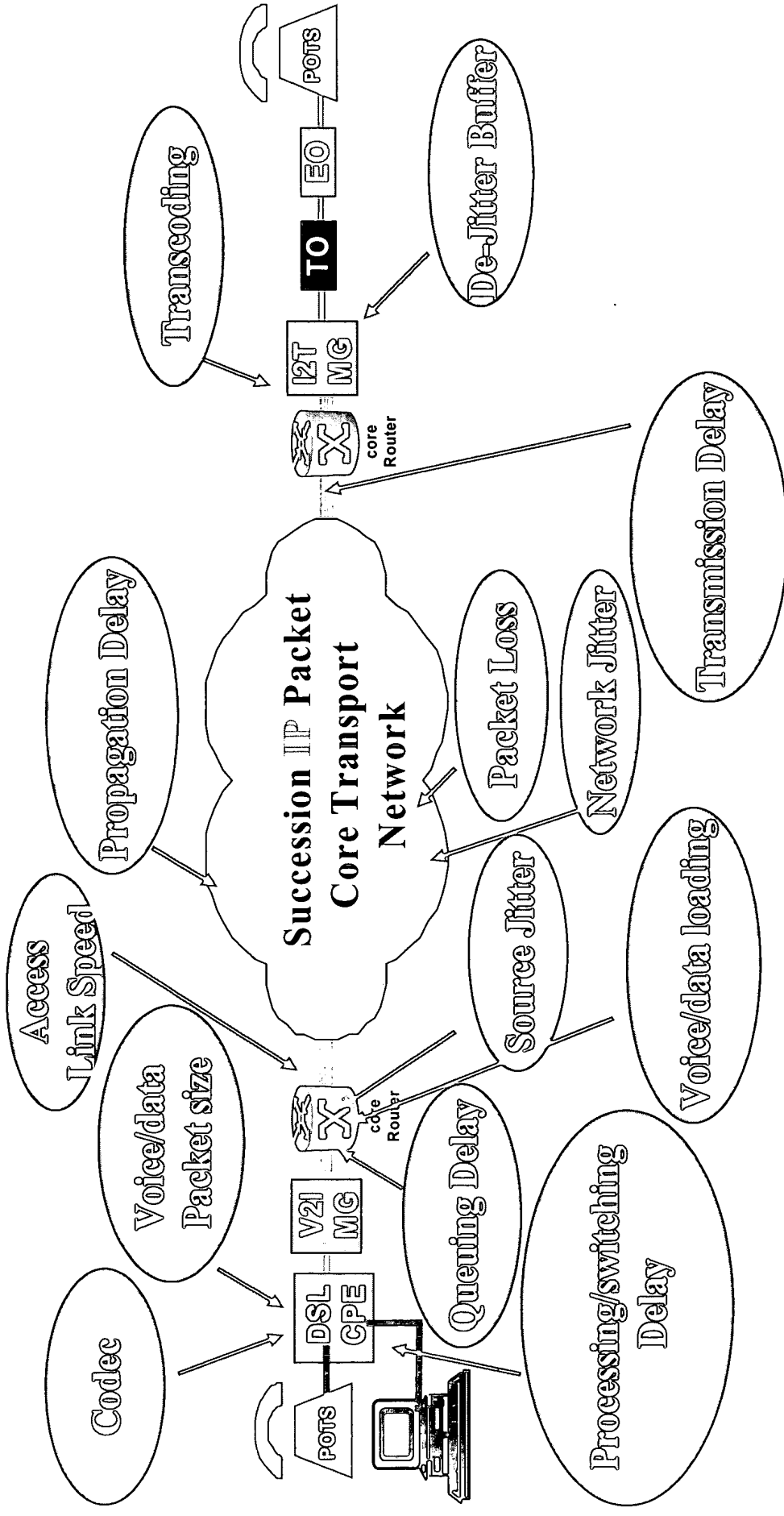
Fig. 44

Trunk Access - ATM Core

POTS — EO — TO — T2A/MG
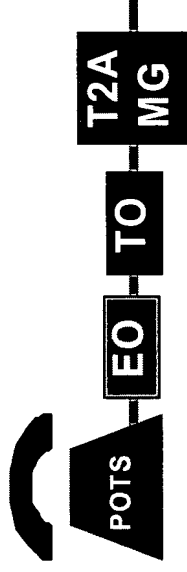
**Trunk Access to ATM Core   (before 4 parameters budget assignment)
Delay, loss and Impairment Summary**

Set delay (Side A) (ms)	0
End Office Delay (Side A) (ms)	1.5
Tandem Office Delay (Side A) (ms)	0.75
T2AMG delay (Side A) (ms)	0.5
Trunk Access delay (ms)	**2.75**
Impairment Factor (Ie)	0

Fig. 45

Wireless Access - IP Core

BTS ··· BSC ··· MSC ··· T2I MG

core Router
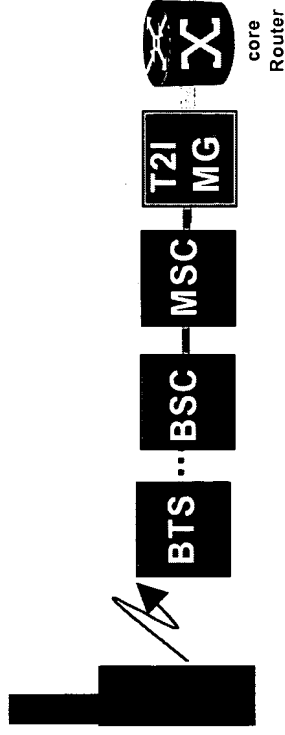
Succession Wireless to ATM Core - Delay, loss ad Impairment Summary (before 4 parameters budget assignment)

	Uplink	Downlink
Mobile Switching Center (MSC) (ms)	1	2
Base Station Controller (BSC) (ms)	2.5	40
Base Station (BTS) (ms)	15.8	40.8
Mobile Set (MS) (ms)	72.1	14.3
T2AMG delay (Side A) (ms)	0.5	0.5
Wireless Access delay (ms)	91.40	97.10
Impairment Factor (Ie)	5	5

Fig. 46

Cable Access - ATM Core
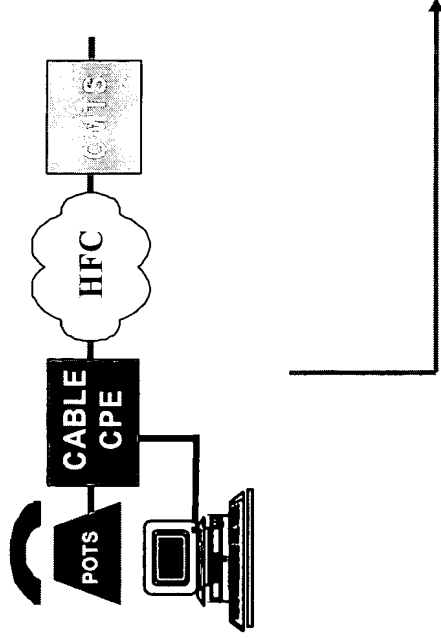
Cable CPE	Cable CPE Upstream	Cable CPE Downstream	Note
Link Speed	510 Kbps	3000 Kbps	
Voice packet size (byte)	160	160	note [1]
Voice packet overhead (RTP/UDP/IP)	48	48	note [2]
Data packet size (byte)	512	512	
Data packet overhead	48	48	
Voice packet link utilization (%)	10.0%	10.0%	
Data packet link utilization (%)	90.0%	90.0%	
Fixed Delay			
- Serialization delay for voice packet (ms)	3.26	0.55	note [3]
- DSP & CPU processing delay (ms)	12.00	14.00	note [4]
- Packetization Delay (ms)	0.00	N/A	note [5]
Variable Delay			
- Average Voice data contention (ms)	4.57	0.78	note [6]
- Maximum Voice data contention (ms)	9.15	1.55	note [6]
- De-Jitter buffer delay (ms)	N/A	0.00	note [5]
Other Impairments			
- Packet Loss (%)	0.00	0.00	note [5]
Minimum Delay (Fixed Delays) (ms)	15.26	14.55	
Average Delay (Fixed+Average Variable Delays) (ms)	19.84	15.33	
Maximum Delay (Fixed+ Max Variable Delays) (ms)	24.41	16.11	

Fig. 47

A- Side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

Core Transport Network
(TDM,ATM or IP)

B- side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

National ATM Transport Core

ECAN   Core Router   ECAN
        IP National
        Transport

International ATM Transport Core

ECAN   Core Router   ATM Sw   Core Router   ATM Sw   Core Router   ECAN
        IP National   IP Inter National   IP National
        Transport   Transport   Transport

International ATM Transport Core with DCME

ECAN   Core Router   ATM Sw   T2I MG   DCME   DCME   T2I MG   ATM Sw   Core Router   ECAN
        IP National   IP International   IP National
        Transport   Transport   Transport

——— G.711 (TDM/ATM)
═══ G.726 (DCME)

Fig. 48

Total National Transport Distance (km)	8000 km (IP)	8000 km (ATM)	8000 km (TDM)	Note
Terrestrial Distance (km)	8000	8000	8000	
Terrestrial propagation Delay @ 5us / km (ms)	40	40	40	From G.114
Submarine Distance (km)	-	-	-	
Submarine propagation Delay @ 6us / km (ms)	-	-	-	From G.114
Number of hop	5	8	4	From i.356, TIA IS-810 G.114
Equipment processing time (ms)	1ms x 5	0.03ms x 8	0.75ms x 4	I.356 QoS class 1
Jitter (ms)	note [1]	1.5 note [3]	0	Note [2]
Total Delay (ms)	45	41.74	43	

Internation Core Transport delay	27500 (IP)	27500 (ATM)	27500 (TDM)	Note
Terrestrial Distance (km)	16000	16000	16000	
Terrestrial Delay @ 5us / km (ms)	80	80	80	
Number of hop	15	19	12	From I.356, TIA IS-810
Equipment processing time per hop	1	0.03	0.75	G.114
Equipment processing time (ms)	15	0.57	9	G.115
Submarine Distance (km)	11500	11500	11500	
Submarine Delay @ 6us / km (ms)	69	69	69	
Jitter (ms)	note [1]	3	0	I.356 QoS class 1
Total Delay (ms)	164	149.57	158	Note [2]

Fig. 49

B- side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

B- Side Access

A- Side Wireless Access

Succession IP Core Transport with 1 DCME

G.711 (TDM/ATM)
IP
Cellular (compressed voice)

Intrinsic R-factor (before parameter budget assuagement)
Total end-to-end intrinsic impairment (before parameter budget assuagement)
Total end-to-end intrinsic delay (before parameter budget assuagement)

Succession IP Core Transport	National			International 0 DCME			International 1 DCME			International 2 DCME		
B-Side Access	T	Ie	R	T	Ie	R	T	Ie	R	T	Ie	R
Trunk	145	5	82	264	5	69	293	12	59	321	19	48
Line	142	5	82	261	5	70	290	12	59	318	19	48
Wireless	237	10	72	356	10	57	385	17	48	413	24	38
VoDSL	164	5	81	283	5	67	312	12	56	340	19	46
Cable	158	5	81	277	5	67	306	12	57	334	19	47
Enterprise MSS	156	5	81	275	5	68	304	12	57	332	19	47
Enterprise IPPBX	172	5	80	291	5	66	320	12	55	348	19	45

Fig. 50

B-side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise)

Succession ATM Packet Core Transport Network

POTS–EO–TO–T2A MG
A-Side Trunk

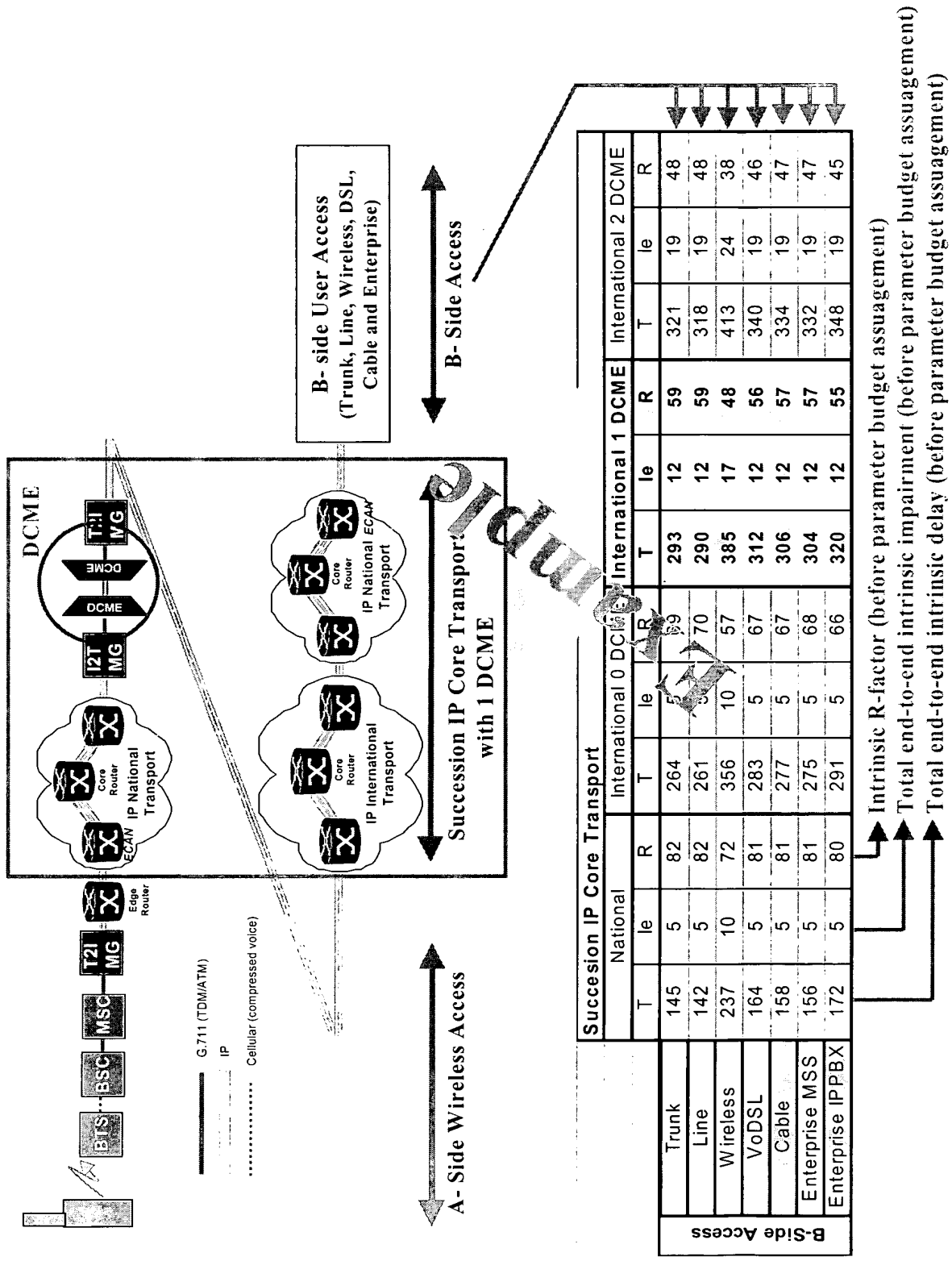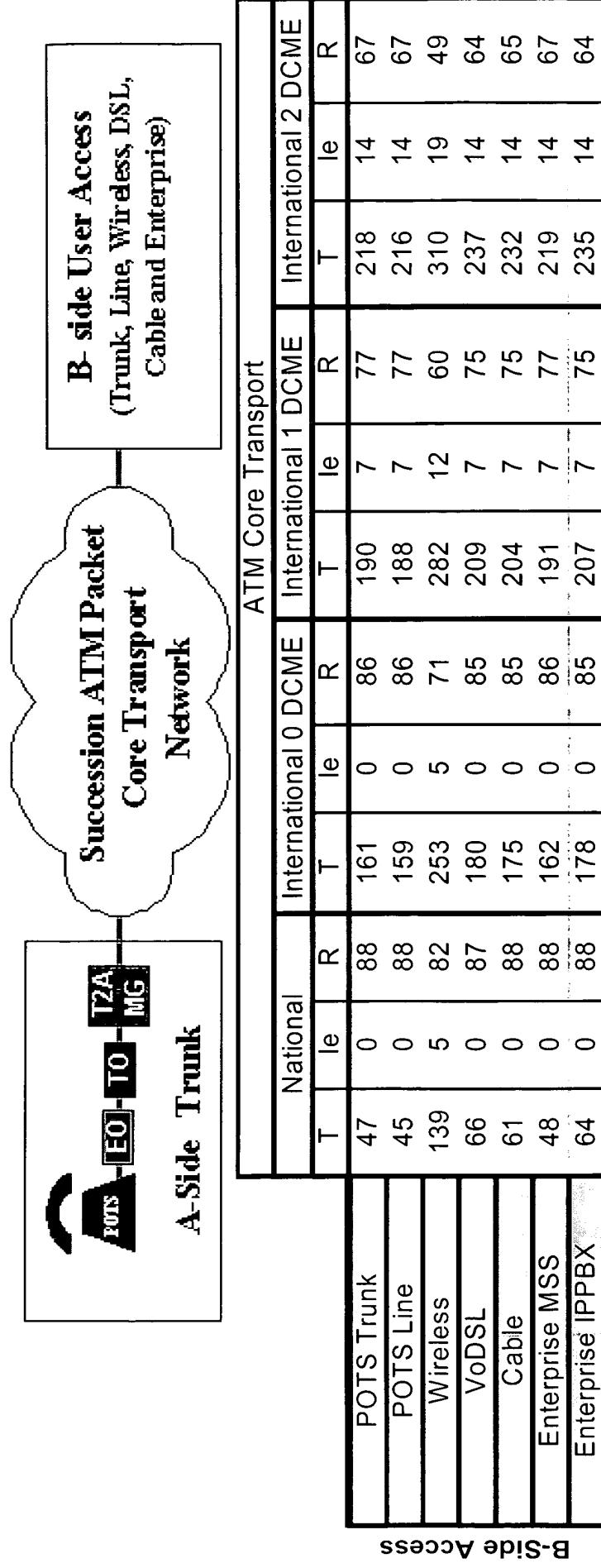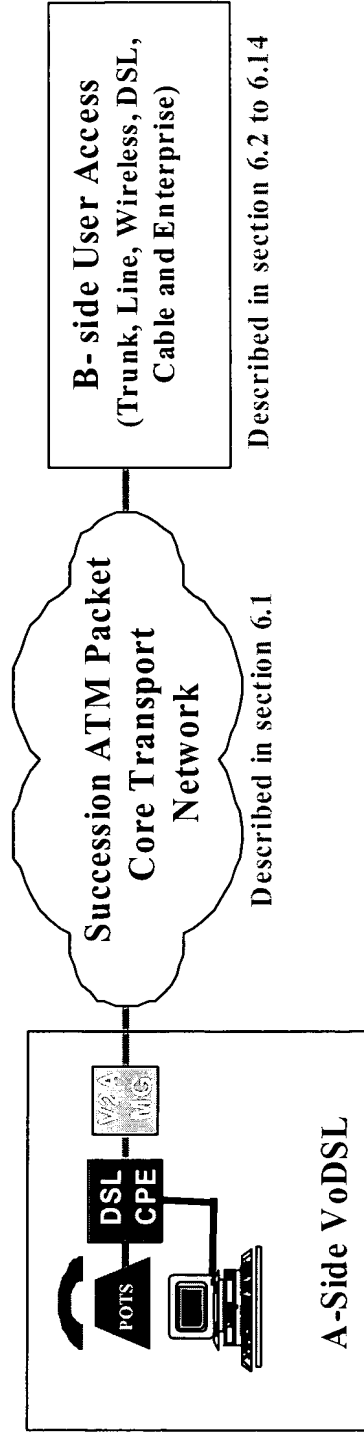|	ATM Core Transport											
	National			International 0 DCME			International 1 DCME			International 2 DCME		
B-Side Access	T	le	R	T	le	R	T	le	R	T	le	R
POTS Trunk	47	0	88	161	0	86	190	7	77	218	14	67
POTS Line	45	0	88	159	0	86	188	7	77	216	14	67
Wireless	139	5	82	253	5	71	282	12	60	310	19	49
VoDSL	66	0	87	180	0	85	209	7	75	237	14	64
Cable	61	0	88	175	0	85	204	7	75	232	14	65
Enterprise MSS	48	0	88	162	0	86	191	7	77	219	14	67
Enterprise IPPBX	64	0	88	178	0	85	207	7	75	235	14	64

Note: The four parameters: packetization delay, delay jitter, codec and packet loss have been set to zero. Those four parameters will be determined based upon the available margin. The margin is determined based on the benchmark comparison of an end-to-end Succession network with the closest benchmark representation of existing networks (PSTN only, mobile to PSTN, or mobile to mobile).

Fig. 51

Succession ATM Packet Core Transport Network

Described in section 6.1

A-Side VoDSL

B- side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

Described in section 6.2 to 6.14

ATM Core Transport

	National			International 0 DCME			International 1 DCME			International 2 DCME		
	T	Ie	R	T	Ie	R	T	Ie	R	T	Ie	R
POTS Trunk	66	0	87	180	0	85	209	7	75	237	14	64
POTS Line	64	0	88	178	0	85	207	7	75	235	14	64
Wireless	158	5	81	272	5	68	301	12	57	329	19	47
VoDSL	86	0	87	200	0	83	229	7	72	257	14	62
Cable	80	0	87	194	0	83	223	7	73	251	14	62
Enterprise MSS	67	0	87	181	0	85	210	7	75	238	14	64
Enterprise IPPBX	84	0	87	198	0	83	227	7	73	255	14	62

B-Side Access

Note: The four parameters: packetization delay, delay jitter, codec and packet loss have been set to zero. Those four parameters will be determined based upon the available margin. The margin is determined based on the benchmark comparison of an end-to-end Succession network with the closest benchmark representation of existing networks (PSTN only, mobile to PSTN, or mobile to mobile).
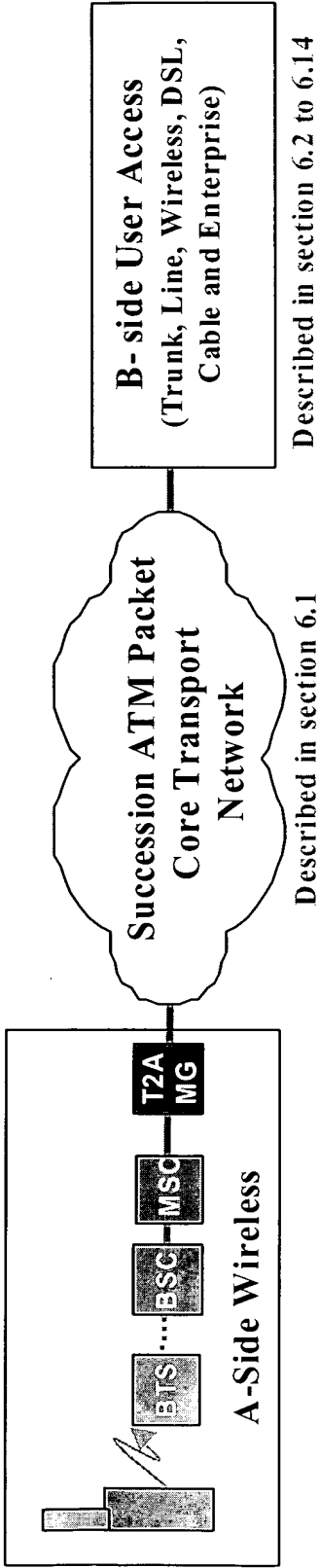
Fig. 52

A-Side Wireless (BTS ···· BSC MSC T2A MG)

Succession ATM Packet Core Transport Network

Described in section 6.1

B-side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise)

Described in section 6.2 to 6.14

IP Core Transport

B-Side Access	National			International 0 DCME			International 1 DCME			International 2 DCME		
	T	Ie	R	T	Ie	R	T	Ie	R	T	Ie	R
POTS Trunk	145	5	86	264	5	74	293	12	63	321	19	53
POTS Line	142	5	86	261	5	74	290	12	64	318	19	53
Wireless	237	10	72	356	10	57	385	17	48	413	24	38
VoDSL	164	5	85	283	5	71	312	12	61	340	19	51
Cable	158	5	85	277	5	72	306	12	62	334	19	52
Enterprise MSS	156	5	85	275	5	72	304	12	62	332	19	52
Enterprise IPPBX	172	5	84	291	5	70	320	12	60	348	19	50

Note: The four parameters: packetization delay, delay jitter, codec and packet loss have been set to zero. Those four parameters will be determined based upon the available margin. The margin is determined based on the benchmark comparison of an end-to-end Succession network with the closest benchmark representation of existing networks (PSTN only, mobile to PSTN, or mobile to mobile).
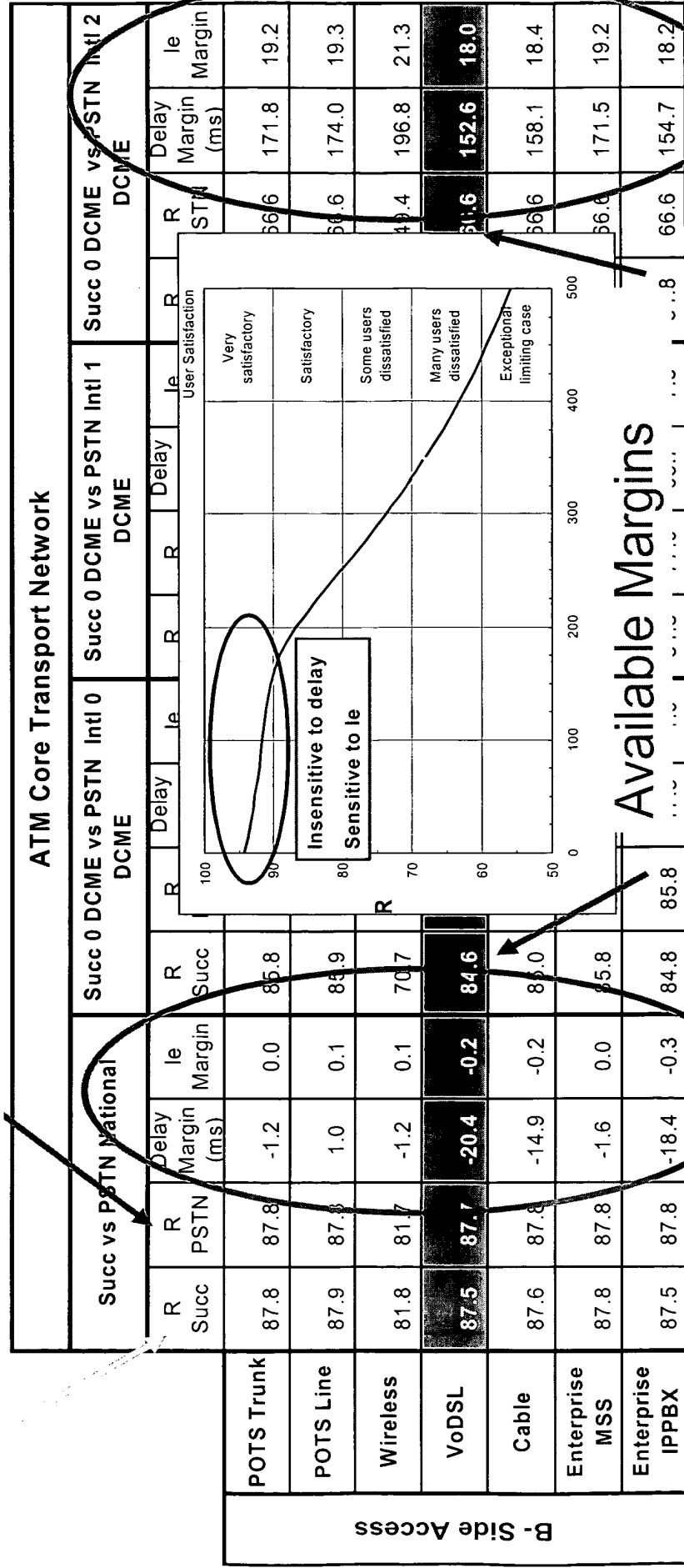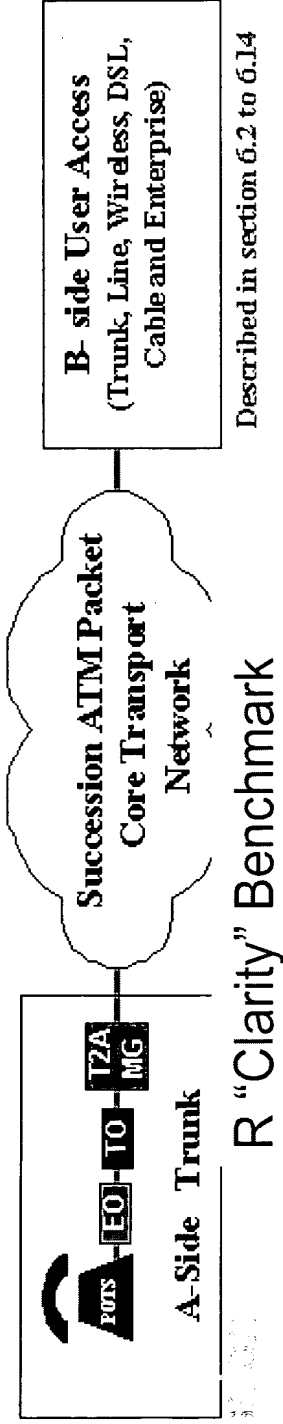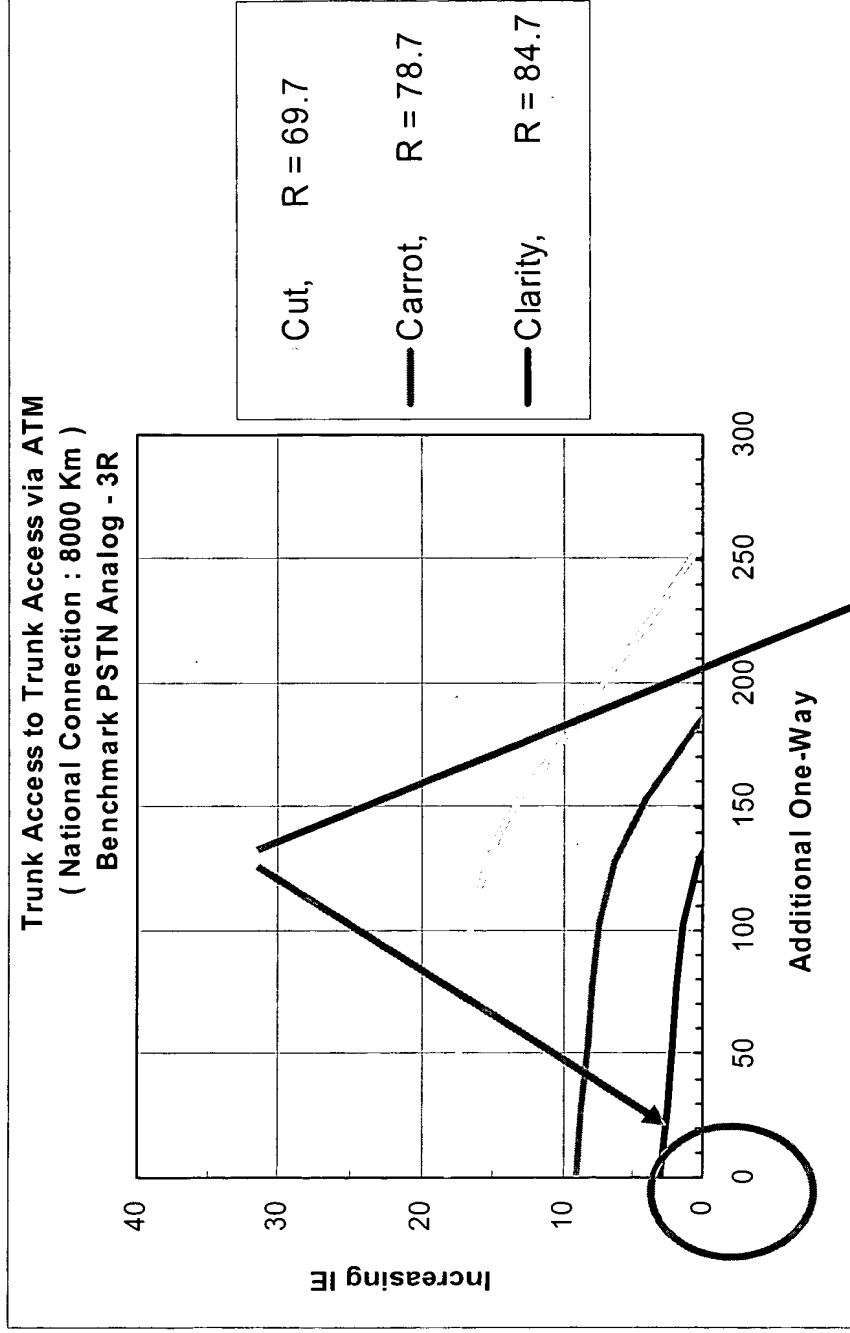
Fig. 53

B-side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

Described in section 6.2 to 6.14

Succession ATM Packet Core Transport Network

A-Side Trunk

POTS — EO — TO — T2A MG

R "Clarity" Benchmark

Available Margins

Insensitive to delay
Sensitive to Ie

User Satisfaction	
	Very satisfactory
	Satisfactory
	Some users dissatisfied
	Many users dissatisfied
	Exceptional limiting case

ATM Core Transport Network

B-Side Access	Succ vs PSTN National				Succ 0 DCME vs PSTN Intl 0 DCME			Succ 0 DCME vs PSTN Intl 1 DCME			Succ 0 DCME vs PSTN Intl 2 DCME		
	R Succ	R PSTN	Delay Margin (ms)	Ie Margin	R Succ			R	Delay	Ie	R STN	Delay Margin (ms)	Ie Margin
POTS Trunk	87.8	87.8	-1.2	0.0	85.8						66.6	171.8	19.2
POTS Line	87.9	87.8	1.0	0.1	85.9						66.6	174.0	19.3
Wireless	81.8	81.7	-1.2	0.1	70.7						49.4	196.8	21.3
VoDSL	87.5	87.7	-20.4	-0.2	84.6						51.6	152.6	18.0
Cable	87.6	87.8	-14.9	-0.2	89.0						66.6	158.1	18.4
Enterprise MSS	87.8	87.8	-1.6	0.0	85.8						66.6	171.5	19.2
Enterprise IPPBX	87.5	87.8	-18.4	-0.3	85.8						66.6	154.7	18.2

Note: In red indicates the worst case access scenario with the smallest available budget

Fig. 54

Trunk Access to Trunk Access via ATM
(National Connection : 8000 Km)
Benchmark PSTN Analog - 3R

Cut,   R = 69.7

Carrot,   R = 78.7

Clarity, R = 84.7

Ie Budget =	3	9	18
Delay Budget =	130	186	257

Fig. 55

Trunk Access to Trunk Access via ATM (0 DCME)
(International Connection : 27,500 Km)
Benchmark PSTN Analog

Legend:
Clarity, R = 66.6
Carrot, R = 66.6
Cut, R = 59.8
AIM Clarity R = 73.6

Y-axis: Increasing IE (0, 10, 20, 30, 40)
X-axis: Additional One-Way Delay (0, 50, 100, 150, 200, 250, 300)
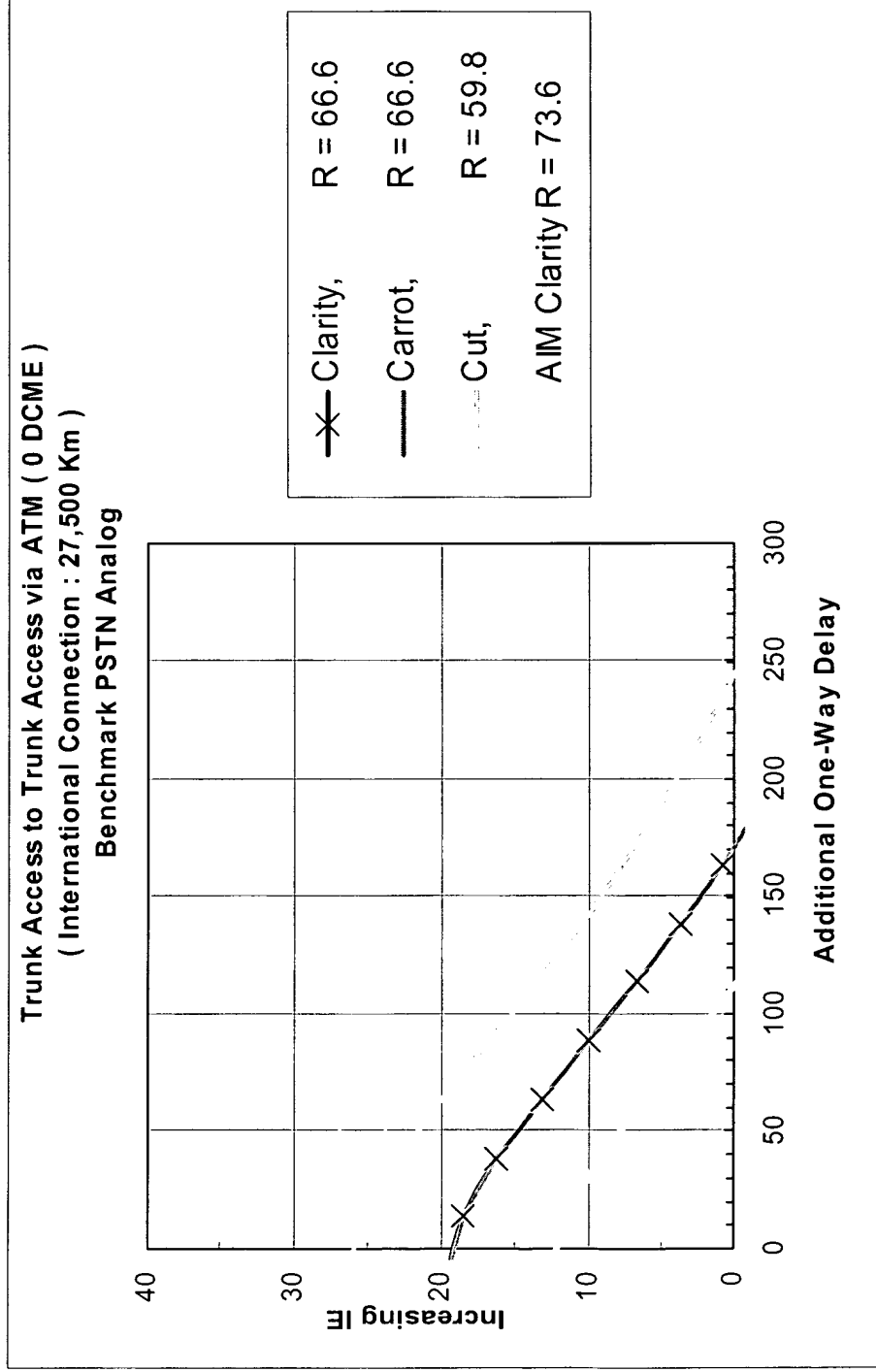
le Budget =	12.07	19.07	19.07	25.87
Delay Budge	110.9	171.5	171.5	244.4

Fig. 56

B- side User Access
(Trunk, Line, Wireless, DSL, Cable and Enterprise)

Described in section 6.2 to 6.14

Succession ATM Packet Core Transport Network

Described in section 6.1

A-Side VoDSL

DSL CPE | POTS | V2A TMG

ATM Core Transport Network

B-Side Access

B-Side Access	Succ vs PSTN National			Succ 0 DCME vs PSTN Intl 0 DCME				Succ 0 DCME vs PSTN Intl 1 DCME				Succ 0 DCME vs PSTN Intl 2 DCME			
	R Succ	R PSTN	Delay Margin (ms)	R Succ	R PSTN	Delay Margin (ms)	le Margin	R Succ	R PSTN	Delay Margin (ms)	le Margin	R Succ	R PSTN	Delay Margin (ms)	le Margin
POTS Trunk	87.5	87.8	-20									84.6	66.6	152.6	18.0
POTS Line	87.5	87.8	-18									84.8	66.6	154.8	18.2
Wireless	81.2	81.7	-20									68.1	49.4	177.6	18.7
VoDSL	87.2	87.7	-39									82.8	66.6	133.4	16.2
Cable	87.3	87.8	-34									83.4	66.6	138.9	16.8
Enterprise MSS	87.5	87.8	-20									84.6	66.6	152.3	18.0
Enterprise IPPBX	87.2	87.8	-37									83.0	66.6	135.5	16.4

Note: In red indicates the worst c...

User Satisfaction

Very satisfactory
Satisfactory
Some users dissatisfied
Many users dissatisfied
Exceptional limiting case

le and delay can be added equally

R

One-way Delay (ms)

Fig. 57

VoDSL Access to VoDSL Access via ATM
(National Connection : 8000 Km)

Increasing IE (y-axis: 0, 10, 20, 30, 40)

Additional One-Way (x-axis: 0, 50, 100, 150, 200, 250, 300)

Legend:
- Cut,   R = 69.7
- Carrot,   R = 78.7
- Clarity, R = 84.8

Ie Budget =	2	8	17
Delay Budget =	92	147	219

Fig. 58

VoDSL Access to VoDSL Access via ATM (0 DCME)
(International Connection : 27,500 Km)
Benchmark PSTN Analog

Clarity   R = 66.6
Carrot   R = 66.6
Cut   R = 59.8
AIM Clarity R = 73.6

Increasing IE

40
30
20
10
0

0   50   100   150   200   250   300

Additional One-Way Delay
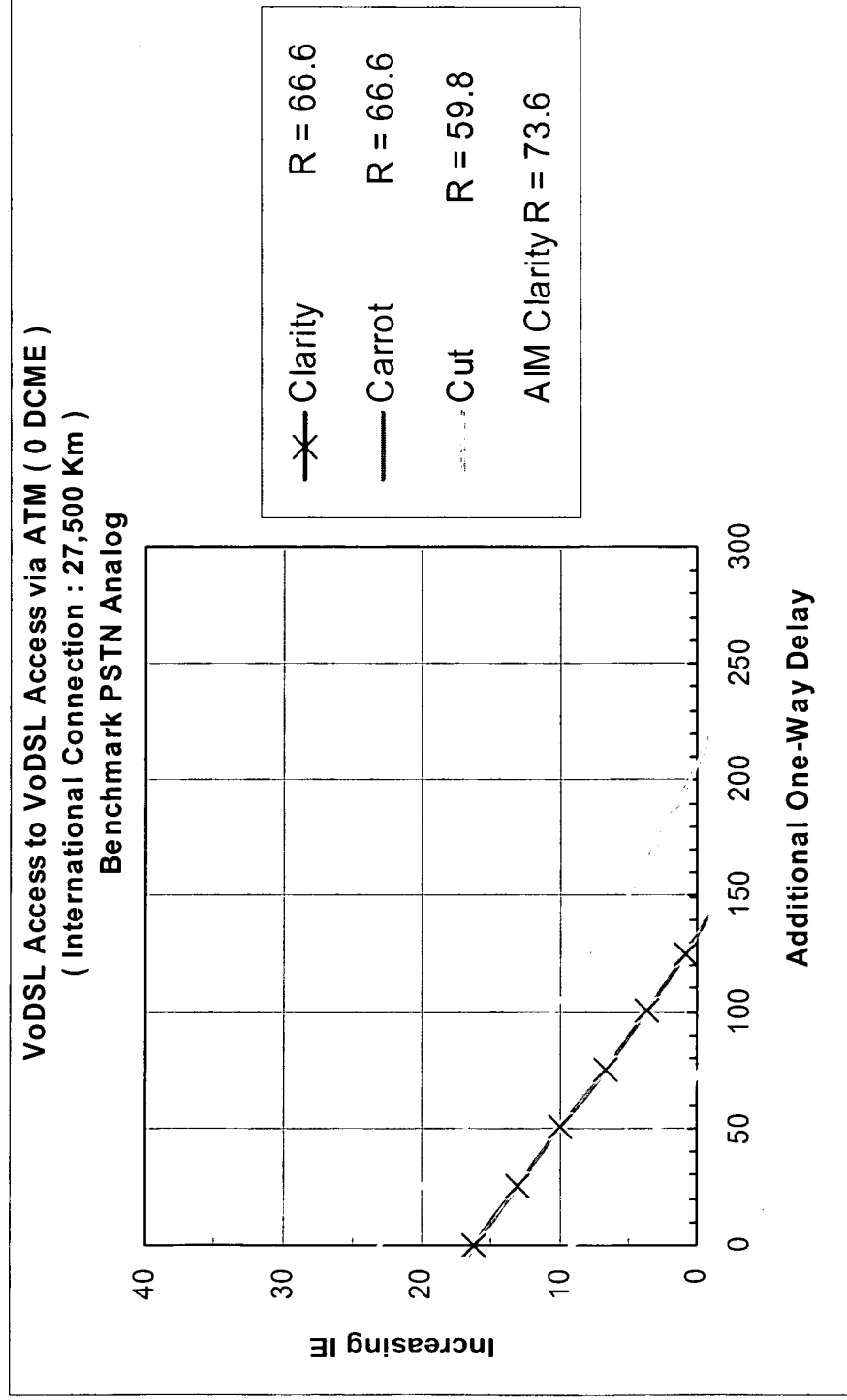
| le Budget = | 9.207 | 16.21 | 16.21 | 23.01 |
| Delay Budget = | 72.54 | 133.1 | 133.1 | 206 |

Fig. 59

A-Side Wireless — BTS · BSC · MSC · T2A MG

Succession ATM Packet Core Transport Network

B-side User Access (Trunk, Line, Wireless, DSL, Cable and Enterprise)
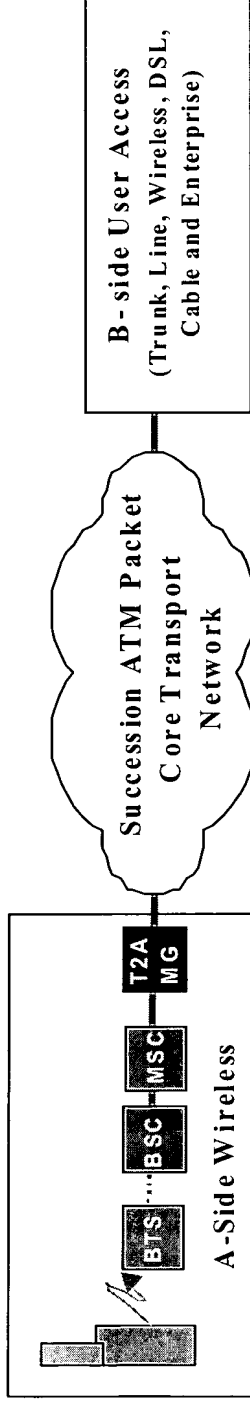
Described in section 6.1

Described in section 6.2 to 6.14

ATM Core Transport Network

B-Side Access	Succ vs PSTN National				Succ 0 DCME vs PSTN Intl 0 DCME				Succ 0 DCME vs PSTN Intl 1 DCME				Succ 0 DCME vs PSTN Intl 2 DCME			
	R Succ	R PSTN	Delay Margin (ms)	Ie Margin	R Succ	R PSTN	Delay Margin (ms)	Ie Margin	R Succ	R PSTN	Delay Margin (ms)	Ie Margin	R Succ	R PSTN	Delay Margin (ms)	Ie Margin
POTS Trunk	81.8	81.7	-1.2	0.1	70.7	70.6	-0.2	0.1	70.7	59.8	91.8	10.9	70.7	49.4	196.8	21.3
POTS Line	81.8	81.7	1.0	0.1	71.0	70.6	2.0	0.4	71.0	59.8	94.0	11.2	71.0	49.4	199.0	21.6
Wireless	72.7	72.7	-0.2	0.0	58.5	58.3	0.8	0.2	58.5	48.5	17.8	10.0	58.5	39.0	192.8	19.5
VoDSL	81.2	81.7	-20.4	-0.5	68.1	70.6	-19.4	-2.5	68.1	59.8	72.6	8.3	68.1	49.4	177.6	18.7
Cable	81.4	81.7	-14.9	-0.3	68.8	70.6	-13.9	-1.8	68.8	59.8	78.1	9.0	68.8	49.4	183.1	19.4
Enterprise MSS	81.8	81.7	-1.6	0.1	70.6	70.6	-0.5	0.0	70.6	59.8	91.5	10.8	70.6	49.4	196.5	21.2
Enterprise IPPBX	81.2	81.7	-18.4	-0.5	68.4	70.6	-17.3	-2.2	68.4	59.8	74.7	8.6	68.4	49.4	179.7	19.0

Note: In red indicates the worst case access scenario with the smallest available budget
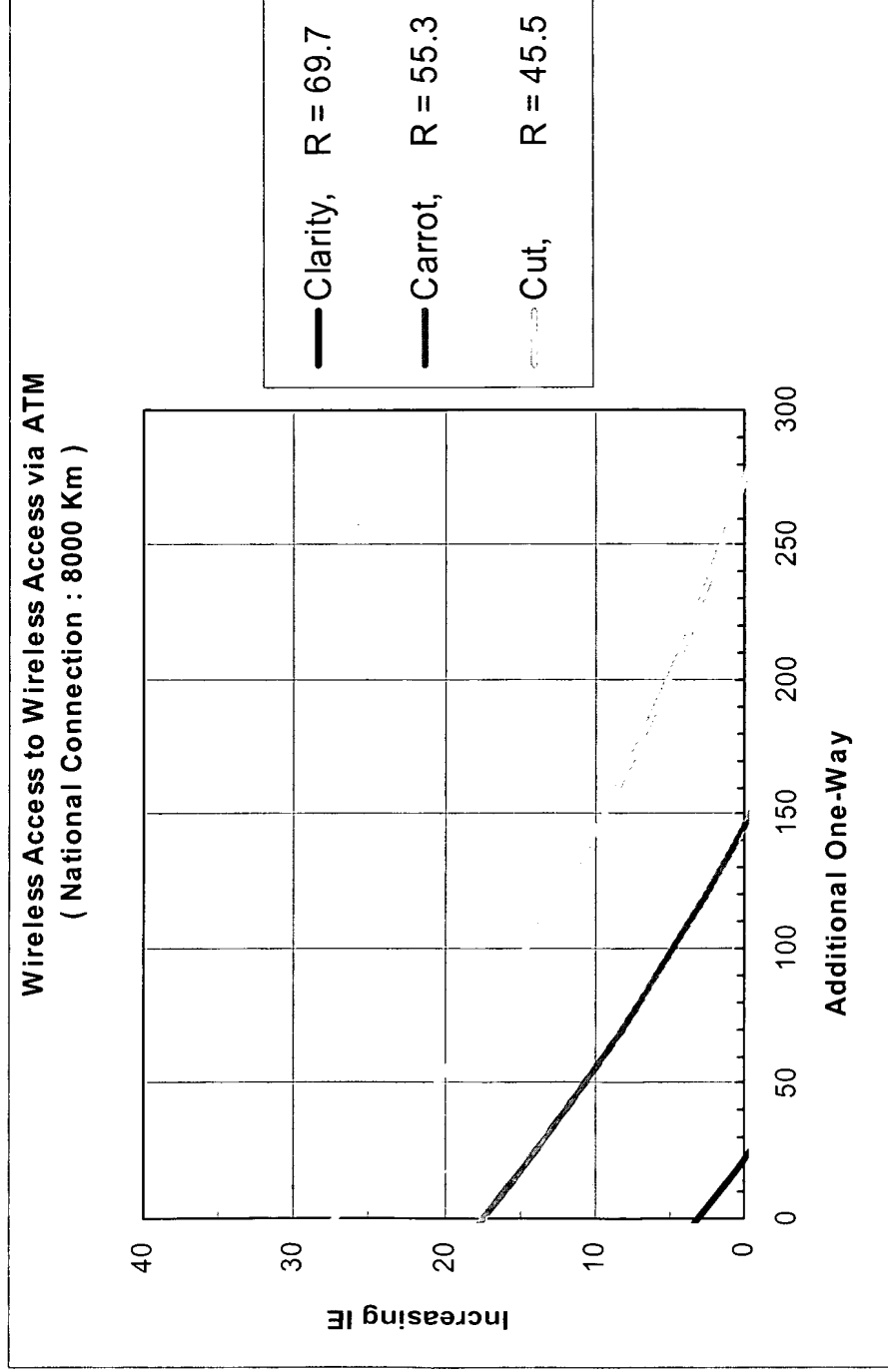
Fig. 60

Wireless Access to Trunk Access ATM Core
(National Connection : 8000 Km)

Increasing IE

40
30
20
10
0

0   50   100   150   200   250   300

Additional One-Way

Cut,   R = 78.7

—Carrot,   R = 69.7

—Clarity,   R = 55.3
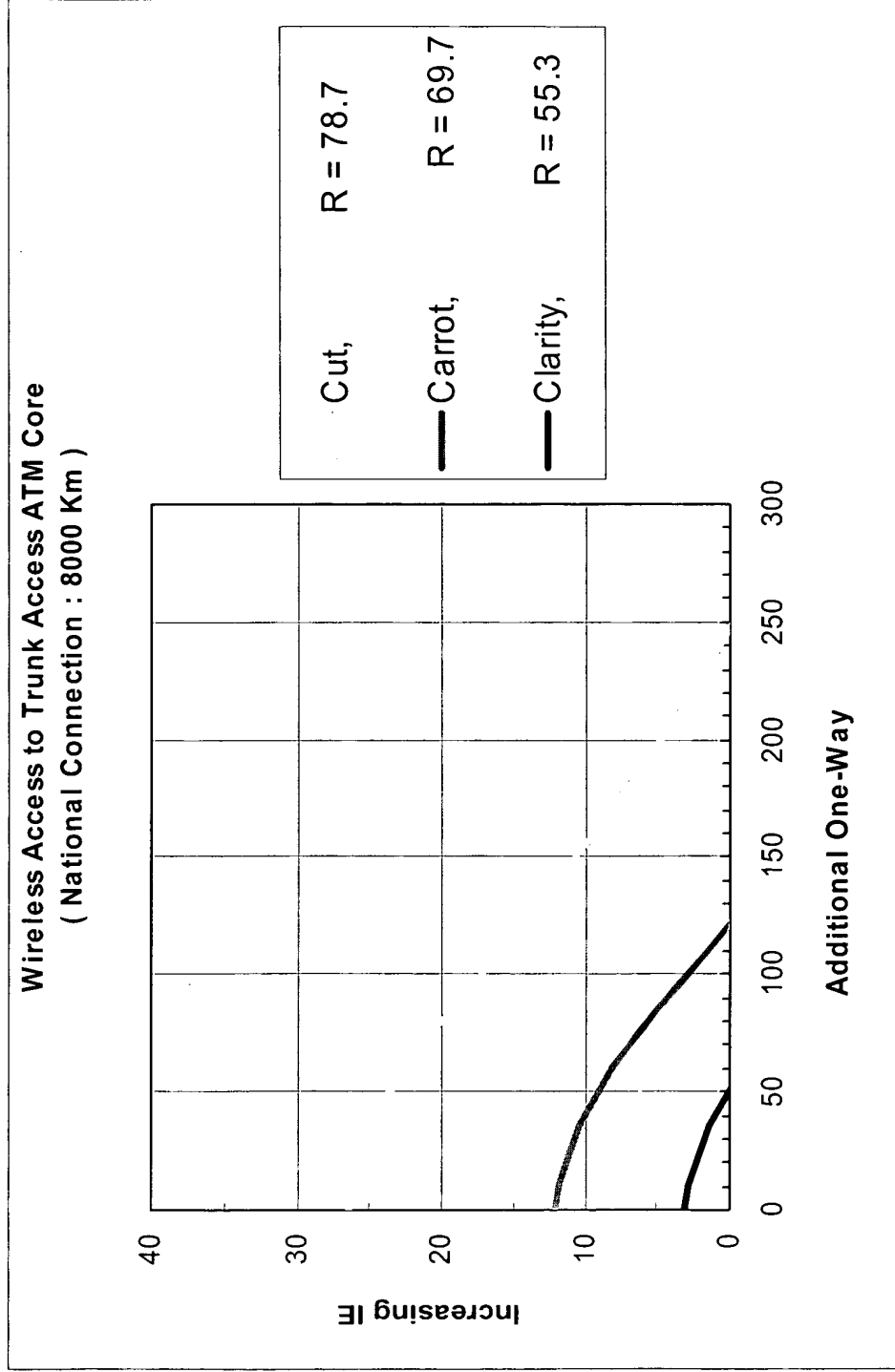
Ie Budget =	3	12	26
Delay Budget =	51	121	249

Fig. 61

Wireless Access to Trunk Access via IP (0 DCME)
(International Connection : 27,500 Km)
Benchmark PSTN Wireless-to-Analog

Legend:
- ✕— Clarity, R = 49.4
- ●— Carrot, R = 49.4
- Cut, R = 48.5
- AIM Clarity, R = 56.4

Y-axis: Increasing IE (0, 10, 20, 30, 40)

X-axis: Additional One-Way Delay (0, 50, 100, 150, 200, 250, 300)
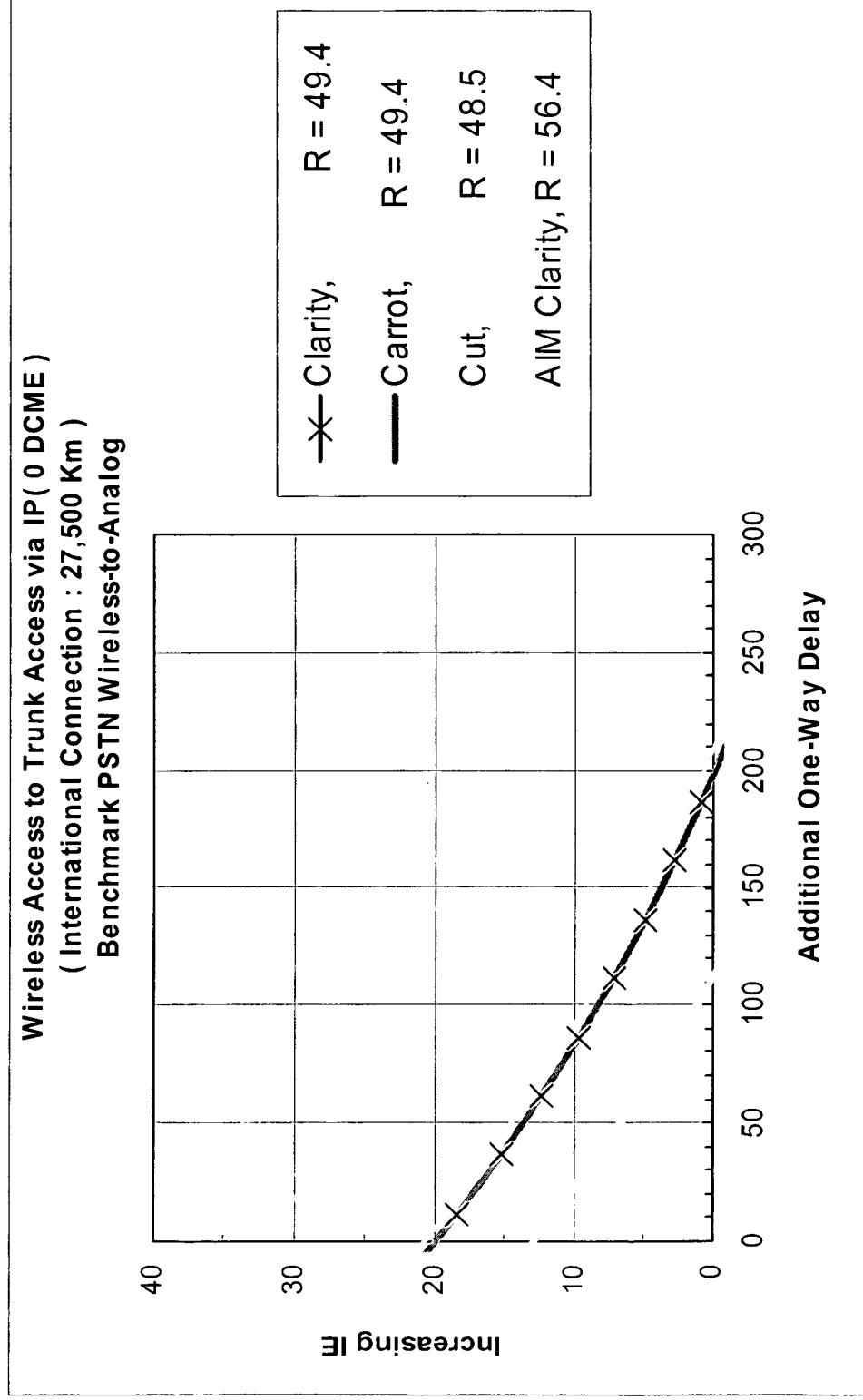
le Budget =	12.91	20	20	20	21
Delay Budget =	112.4	197	197	197	210

Fig. 62

Wireless Access to Wireless Access via ATM
(National Connection : 8000 Km)

Clarity,   R = 69.7

Carrot,   R = 55.3

Cut,   R = 45.5

[Graph: Increasing IE (y-axis, 0 to 40) vs. Additional One-Way (x-axis, 0 to 300)]

| Delay Budget = | 3.004 | 17.34 | 27.14 |
| le Budget = | 21.97 | 145.8 | 273.1 |

Fig. 63

Wireless Access to Wireless Access via ATM (0 DCME)
(International Connection : 27,500 Km)
Benchmark PSTN Wireless-to-Wireless

Legend:
- Clarity,   R=39
- Carrot,   R=39
- Cut,   R = 39
- AIM Carrot,   R = 56
- AIM Clarity,   R = 56

Y-axis: Increasing IE (0, 10, 20, 30, 40)
X-axis: Additional One-Way Delay (ms) (0, 50, 100, 150, 200, 250, 300)
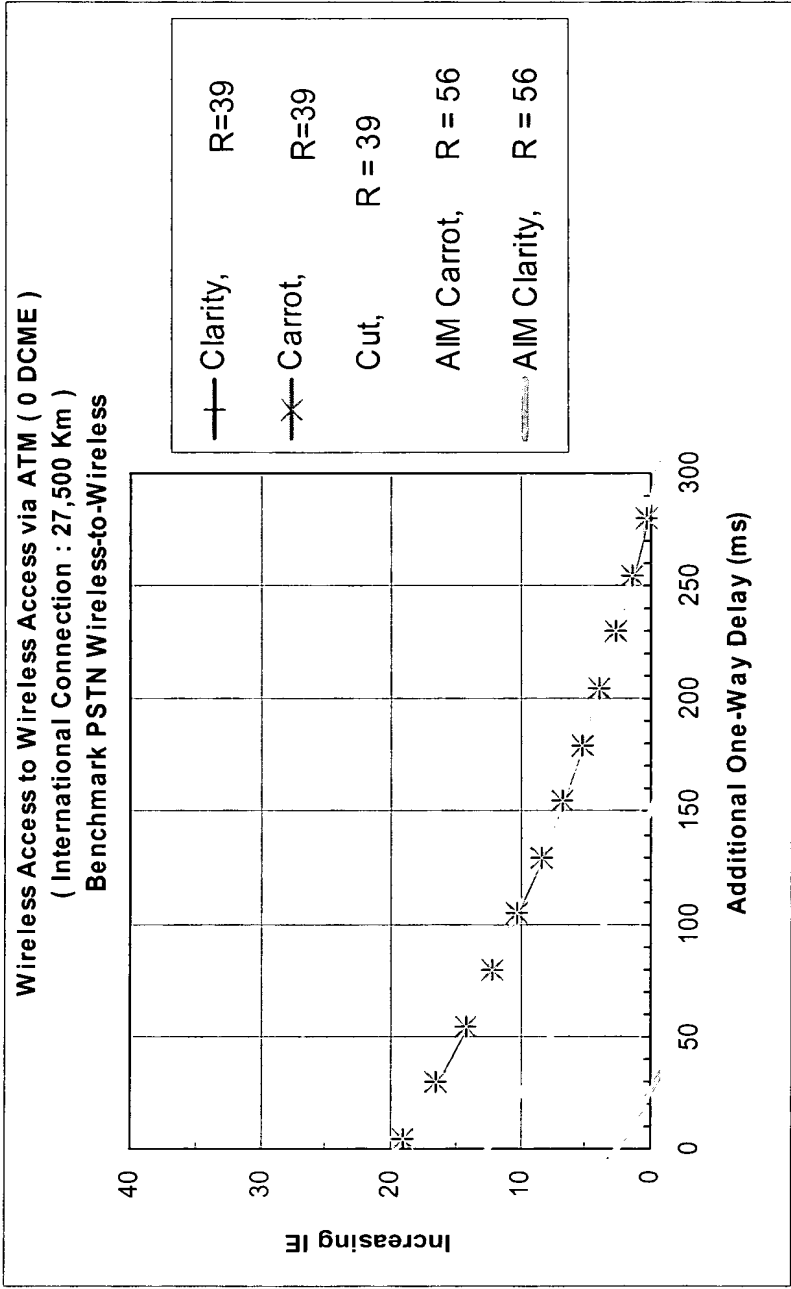
| le Budget = | 2 | 12 | 19 | 19 | 19 |
| Delay Budget = | 25 | 151 | 181 | 248 | 289 |

Fig. 64

Rank	Codec	E-model Impairment Factor (Ie)	Estimated implementation delay (ms)	Note
1	G.711 at 64 kb/s	0	0.125	PCM
2	G.726 at 32 kb/s with Synch Coding	7	0.250	ADPCM
3	GSM-EFR	5	40	GSM
4	IS-733	*	40	
5	G.728 at 16 kb/s	7	1.250	
6	G.729/G.729A at 8 kb/s	10/11	25	
7	IS-641	6	40	TDMA
8	G.723.1 at 6.3 kb/s (not recommended)	15	30	Soft Phone

Fig. 65

Codec		packetization delay (ms)	max packet loss (%)	le due to packet loss
type	Codec le			
G.711	0	10	0%	0
G.711	0	20	0%	0
G.726(1)	7	10	0%	0

1. This codec is only really suitable for international

Fig. 66

Codec		packetization delay (ms)	max packet loss (%)	Ie due to packet loss
type	Codec Ie			
G.711	0	10	0%	0
G.711	0	20	0%	0
G.711	0	40	0%	0
G.726	7	10	0%	0
G.726	7	20	0%	0
G.726	7	40	0%	0
G.711	0	10	1%	5
G.711	0	20	1%	5

Fig. 67

Codec		packetization delay (ms)	max packet loss (%)	le due to packet loss
type	Codec le			
G.711	0	10	0%	0
G.711	0	20	0%	0
G.711	0	40	0%	0
G.726	7	10	0%	0
G.726	7	20	0%	0
G.726	7	40	0%	0
G.729	11	10	0%	0
G.729	11	20	0%	0
G.729	11	40	0%	0
G.711	0	10	1%	5
G.711	0	20	1%	5
G.711	0	40	1%	5
G.726	7	10	1%	2
G.726	7	20	1%	4
G.726	7	40	1%	8
G.729	11	10	1%	2
G.729	11	20	1%	4

Fig. 68

Fig. 69

Hong Kong/
Australia

USA

Europe

ATM/IP

ATM/IP

ATM/IP

GSM

QCELP

DSLAM

DSLAM

DSLAM

GSM

GSM/AAL2

QCELP

G.711, G.726, AMR

G.711, G.726/AAL2

G.711, G.726, AMR

G.711, G.726, AMR/AAL2

G.711/G.726/AMR

G.711,G.726, QCELP/AAL2

G.711

Fig. 70

EO - End Office
TO - Tandem Office
TrO - IXC Transit Office

TrO
ECAN

TO

TrO
ECAN

lumped national model

27,500km

lumped international model

lumped national model

Fig. 71

Analogue

UEMG
Line
Gateway

Wireless
Gateway

Wireless
Access

AAL2

AAL1

SMG4000
Trunk
Gateway

TDM

xDSL

UEMG
DSL
Gateway

LVG
(Interworking)
Media
Gateway

Fig. 72

QCELP,
GSM,
AMR

H.248

AAL-2

CS

SIP-T (ISUP, SDP etc.)

H.248

IMG

H.248

CS

MG

G.711

ATM, IP, MPLS etc.

AAL-2

MG

G.711

DSLAM

G.711, G.726/7/8/9
(AAL-2, IP/AAL-5)

DSLAM

G.711, G.726/7/8/9
(AAL-2, IP/AAL-5)

QCELP,
GSM,
AMR

731

REQUIREMENTS

733

MODELLING MODULE

732

FACTORS

COMPARISON MODEL

COMPARE

734

735

OUTPUT

736

Fig 73